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Bulletin No. 10

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— THE —
MINERALS OF THE BLACK HILLS

BY

VICTOR ZIEGLER

Rapid City, South Dakota
February, 1914

South Dakota School of Mines

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Department of Geology and Mineralogy

— THE —

MINERALS OF THE BLACK HILLS

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Minerals of the Black Hills

Victor Ziegler

Letter of Transmittal

South Dakota School of Mines,
Rapid City, February 12, 1914.

Sir: I have the honor to transmit herewith a paper by Professor Victor Ziegler of the department of Mineralogy and Petrography, entitled "The Minerals of the Black Hills." The paper is an important one and should prove of value to all who may be interested in the minerals of the Black Hills region.

I submit the paper with the recommendation that it be published as Bulletin No. 10 of the South Dakota State School of Mines.

Respectfully.
CLEOPHAS C. O'HARRA, President

HON. A. E. HITCHCOCK,
President Regents of Education

South Dakota School of Mines
Rapid City

PREFACE

The Black Hills region is one of the most remarkable mineral areas of the world because it comprises within its limited area not only a great variety of minerals, but also an abundance of rare species, some of which are not known elsewhere. Articles describing these minerals are scattered through different scientific journals inaccessible to the greater part of the people of the state. These deal only with some of the rarer minerals, or in the more strictly economic and geologic discussions give no more than mere mention to the great majority of species.

The lack of a brief summary of the mineralogy of the Black Hills has hence frequently been felt, and it was to supply this need that the writer undertook to prepare this paper. The main purpose was to describe as far as possible all the minerals known from the Black Hills in such a way that the bulletin might be of service to the citizens of the state, and especially to the miner, prospector, and student. A certain number of scientific terms must of necessity be used in such descriptions, but the number has been restricted as much as possible, and those used are fully explained in the general introductory statements which also present a few facts of the science of mineralogy practically essential to the complete understanding of the detailed descriptions.

Crystal forms occurring on the different species have received mention, but no crystal angles are given, as all determinations made by the author rest on measurements with a contact goniometer.

To make the bulletin serviceable there have been included several tables for the identification of minerals by physical properties alone. The tables were designed to apply to Black Hills minerals only, and it is believed that with sufficient care any one will be enabled to determine the great majority of minerals which he may encounter. No originality is claimed for them, as in general they are based on the same scheme as the majority of such tables now in existence.

It is also hoped that the scientist may find something of interest in these pages, and while errors both of commission and omission are undoubtedly present, he will find mentioned and described, though incompletely, all minerals at present known from the Black Hills.

I wish to express my obligation here to the many scientists who have gone before me in this field, and from whose pages I have freely drawn whatever matter I needed. As far as practicable, all information obtained from literature has been duly acknowledged, usually by a number which has reference to the articles listed in the accompanying bibliography. The introductory portion is in part based on Braun's "Das Mineralreich."

I am indebted to Mr. W. C. Bochert, student assistant in Geology and Mineralogy at the State School of Mines, for careful painstaking work in the preparation of crystal drawings. I am also indebted to Professor M. F. Coolbaugh of the State School of Mines, for placing at my disposal a series of chemical analyses, and to Dr. Herman Reinbold, Mr. Ed. N. Davis, and Mr. Samuel Scott for information rgarding the occurrence of several minerals. Most of the photographs reproduced in the halftones accompanying the paper were made by Mr. H. F. Quiggle, to whom my thanks are due for the special effort and care used in their preparation.

My thanks must also be expressed to the following gentlemen for the kindness extended while the author was engaged in field work: Ed. N. Davis, A. M. Lane, William Gerard, Tom Penaluna, Lou Everly, John Moody, Van Woehrman, William Petit, J. B. Kamman, Frank Hebert, Dennis Henault, L. W. Stillwell, Carriers, John Truax, J. N. Smith and many others.

My deepest gratitude must be expressed to President C. C. O'Harra for his unfailing readiness to give the writer the benefit of all of his knowledge of Black Hills mineralogy. His unfailing sympathy and constant encouragement have not only kept alive my interest in this subject, but deserve much credit for whatever merit the following pages may possess.

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B. Description of Minerals.
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  (b) Individual Description.
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    II. Sulphides, Arsenides.
    III. Sulph-antimonides, sulph-arsenides.
    IV. Haloids.
    V. Oxides.
    VI. Oxygen Salts.
      a. Carbonates.
      b. Silicates.
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MINERALOGY.

Mineralogy is the science covering the study of the materials making up the planet upon which we live, except those which we designate as living and those which are a result of organic processes. The single units of which the earth's material is made up are called minerals. These may be defined as inorganic substances occurring in nature that have a definite chemical make-up. Minerals are the very means upon which all life on earth is dependent. Plants find sustenance in the phosphorous, the silica, the alkalies and other elements which are locked up in the minerals, and in the carbon, oxygen, and nitrogen included in our atmosphere. Animals either directly or indirectly are entirely dependent for food on plants and hence ultimately on minerals. Man uses minerals as the physical basis of his whole civilization. Gold and silver, upon which our highly developed system of commercial exchange is based, must first be obtained from the inexhaustible storehouse of nature. Copper, iron and all the other metals must, before they are available for our industrial enterprises, be secured in some mineral form. Our building stones, wall plasters, cements, paints, borax, baking soda are natural products. Gems, like the "flowers" among the plants, are the recognized ornaments of the beautiful. But, unlike flowers, their beauty never fades. Their color maintains its wondrous hue forever, and their luster will afford the same fire and sparkle millions of years later as well as on the day they were first formed. No artificial product will ever have their depth of color, their brilliancy, nor their hardness.

But the mineral kingdom is not content with furnishing us our medium of exchange, the raw materials for our homes and office buildings, for our railways, for our electric industries (such as telegraph, telephone, power and light), our fuel, our ornaments and jewelry, and indirectly our food and clothing, but also give us remedies for humanities' many ills in the form of mineral springs and yields us the majority of medicines directly as minerals.

Let us hope, then, that the importances of minerals may be sufficiently well recognized that we may look upon these natural objects with some interest, not merely as a possible source of wealth, but in order to gain a better insight into nature and her products, so bountifully displayed everywhere about us.

TABLE OF ELEMENTS.*

(The atomic weights are calculated on the basis of 0=16)

NAME	SYMBOL	ATOMIC WEIGHT.	STATE**	DISCOVERER.	DATE.
Aluminum	Al	27.1	Solid	Woehler	1827
Antimony	Sb	120.2	"	Valentine	1460
Argon	A	39.9	Gas	Rayleigh and Ramsay	1895
Arsenic	As	75.0	Solid	Schroeder	1694
Barium	Ba	137.37	"	Davy	1808
Bismuth	Bi	208.0	"	Agricola	1529
Boron	B	11.0	"	Davy	1807
Bromine	Br	79.92	Liquid	Balard	1826
Cadmium	Cd	112.40	Solid	Stromeyer	1817
Caesium	Cs	132.81	"	Bunsen	1860
Calcium	Ca	40.09	"	Davy	1808
Carbon	C	12.00	"	Ancients	....
Cerium	Ce	140.25	"	Berz. & Hisinger	1803
Chlorine	Cl	35.46	Gas	Scheele	1774
Chromium	Cr	52.1	Solid	Vauquelin	1797
Cobalt	Co	58.97	"	Brandt	1733
Columbium	Cb	93.5	"	Hatchett	1803
Copper	Cu	63.57	"	Ancients	....
Dysprosium	Dy	162.5	"	....	
Erbium	Er	167.4	"	Mosander	1843
Europium	Eu	152.0	"	....	
Fluorine	F	19.0	Gas	Moissan	1886
Gadolinium	Gd	157.3	Solid	....	
Gallium	Ga	69.9	"	De Boisbaudran	1875
Germanium	Ge	72.5	"	Winkler	1886
Glucinum	Gl	9.1	"	Woehler	1828.
Gold	Au	197.2	"	Ancients	....
Helium	He	4.0	Gas	Ramsay	1895
Hydrogen	H	1.008	"	Cavendish	1766
Indium	In	114.8	Solid	Reich & Richter	1863
Iodine	I	126.92	"	Courtois	1812
Iridium	Ir	193.1	"	Tennant	1804
Iron	Fe	55.85	"	Ancients	....
Krypton	Kr	81.8	Gas	Ramsay	1895
Lanthanum	La	139.0	Solid	Mosander	1839
Lead	Pb	207.10	"	Ancients	....
Lithium	Li	7.00	"	Davy	1818

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*Taken from Frazer and Brown, Tables for the Determination of Minerals.

**At ordinary temperatures.

NAME	SYMBOL	ATOMIC WEIGHT.	STATE**	DISCOVERER.	DATE.
Lutecium	Lu	174.0	"		
Magnesium	Mg	24.32	"	Davy	1808
Manganese	Mn	54.93	"	Gahn	1774
Mercury	Hg	200.0	Liquid	Ancients	
Molybdenum	Mo	96.0	Solid	Hjelm	1782
Neodymium	Nd	144.3	"		
Neon	Ne	20.0	Gas	Ramsay	1895
Nickel	Ni	58.68	Solid	Cronstedt	1751
Nitrogen	N	14.01	Gas	Rutherford	1772
Osmium	Os	190.9	Solid	Tennant	1803
Oxygen	O	16.00	Gas	Priestly	1774
Palladium	Pd	106.7	Solid	Wollaston	1803
Phosphorus	P	31.0	"	Brandt	1669
Platinum	Pt	195.0	"	Wood	1741
Potassium	K	39.10	"	Davy	1807
Praseodymium	Pr	140.6	"		
Radium	Ra	226.4	"	Curie	1903
Rhodium	Rh	102.9	"	Wollaston	1803
Rubidium	Rb	85.45	"	Bunsen	1860
Ruthenium	Ru	101.7	"	Claus	1845
Samarium	Sa	150.4	"	De Boisbaudran	1885
Scandium	Sc	44.1	"	Nilson	1879
Selenium	Se	79.2	"	Berzelius	1817
Silicon	Si	28.3	"	Berzelius	1823
Silver	Ag	107.88	"	Ancients	
Sodium	Na	23.00	"	Davy	1807
Strontium	Sr	87.62	"	Davy	1808
Sulphur	S	32.07	"	Ancients	
Tantalum	Ta	181.0	"	Ekeberg	1802
Tellurium	Te	127.5	"	Klaproth	1798
Terbium	Tb	159.2	"	Mosander	1843
Thallium	Tl	204.0	"	Crookes	1861
Thorium	Th	232.42	"	Berzelius	1829
Thulium	Tm	168.5	"	Cleve	1879
Tin	Sn	119.0	"	Ancients	
Titanium	Ti	48.1	"	Klaproth	1794
Tungsten	W	184.0	"	De Luyart	1786
Uranium	U	238.5	"	Peligot	1841
Vanadium	V	51 2	"	Sefstroem	1830
Xenon	Xe	128.0	Gas	Ramsay	1895
Ytterbium (Neoytterbium.)	Yb	172.0	Solid	Marignac	1872
Yttrium	Y	89.0	"	Woehler (?)	1843
Zinc	Zn	65.7	"	Mentioned by Paracelsus	1540
Zirconium	Zr	90.6	"	Berzelius	1824

**At ordinary temperatures.

ELEMENTS AND COMPOUNDS.

The chemists recognizes as elements those substances which cannot be decomposed, that is divided into others by any process known. About eighty elements are known at present. For the sake of simplicity in expression. a certain letter (often two) is chosen as the symbol for each element. These letters usually form the beginning of that word, either in English or Latin, which stands for the particular element. An example will make this clear:

Element.	Symbol.
Aluminum	Al
Manganese	Mn
Zinc	Zn
Carbon	C
Lead (latin Plumbum)	Pb
Iron (latin Ferrum)	Fe
Gold (latin Aurum)	Au

As distinguished from element, the chemist applies the name compound to any substance consisting of a combination. The term "compound" is not applied to mere mixtures, for in no mechanical way known can we divide a compound into its component elements. Furthermore, in studying the different compounds chemists have discovered that elements always combine in some definite proportion by weight. Thus a certain compound made up of Aluminum and oxygen always contains 52.9% of aluminum and 47.1% of oxygen. This relationship between the different elements has enabled chemists to construct a table of "atomic" weights which shows the relative weight of the unit of combination, i. e., the "atom" in which the elements (*) combine with each other. An element is hence indicated by a single symbol; a compound is indicated by writing the symbol for each element present and writing behind it the number of units or atoms necessary to make the right proportion. Thus ferous sulphate is written $FeSO_4$, showing that it is made up in the proportion of one atom of iron, one atom of sulphur, and four atoms of oxygen. Calcium carbonate is represented symbolically by $CaCO_3$, showing that one atom of Calcium, one of carbon and three of oxygen are necessary for this compound. In the same way the symbols for any other compound may be interpreted. A mineral may be an element or a compound. Sulphur (S), Graphite (G), and Gold (Au) are minerals occurring as elements in the Black Hills. Examples of minerals that are chemical compounds are gypsum ($CaSO_4 2H_2O$), siderite ($FeCO_3$), and orthoclase ($KAlSi_3O_8$).

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*See above table.

ROCKS AND MINERALS.

We define a mineral as a natural inorganic compound of a definite chemical composition. Rocks are usually made up of a number of minerals, for an example we only need to recall the appearance of the granite from the Harney Peak region. As a rule it is made up of an aggregate of grains which are of three kinds. One has a glassy appearance, breaks with irregular curving surfaces as glass does, is transparent, and usually colorless. It is much harder than a knife. A second is usually white to pale yellowish in color and breaks with smooth shiny surfaces. In hardness it equals ordinary steel. The third is usually colorless, splits up into exceedingly thin paperlike, flexible flakes which are transparent and can very readily be cut with a knife. The diversity of these characteristics shows at once that we have three minerals in this rock. They are respectively quartz, feldspar, and muscovite (a colorless mica). Contrasted with the above we have gypsum ($CaSO_4.2H_2O$) occurring in nature both as a mineral and as a rock. We find scattered through many shales (a consolidated mud) small transparent plates of this calcium sulphate. As compared to the mass of the formation in which it occurs it is not important. In other cases, however, gypsum makes up layers thirty and more feet in

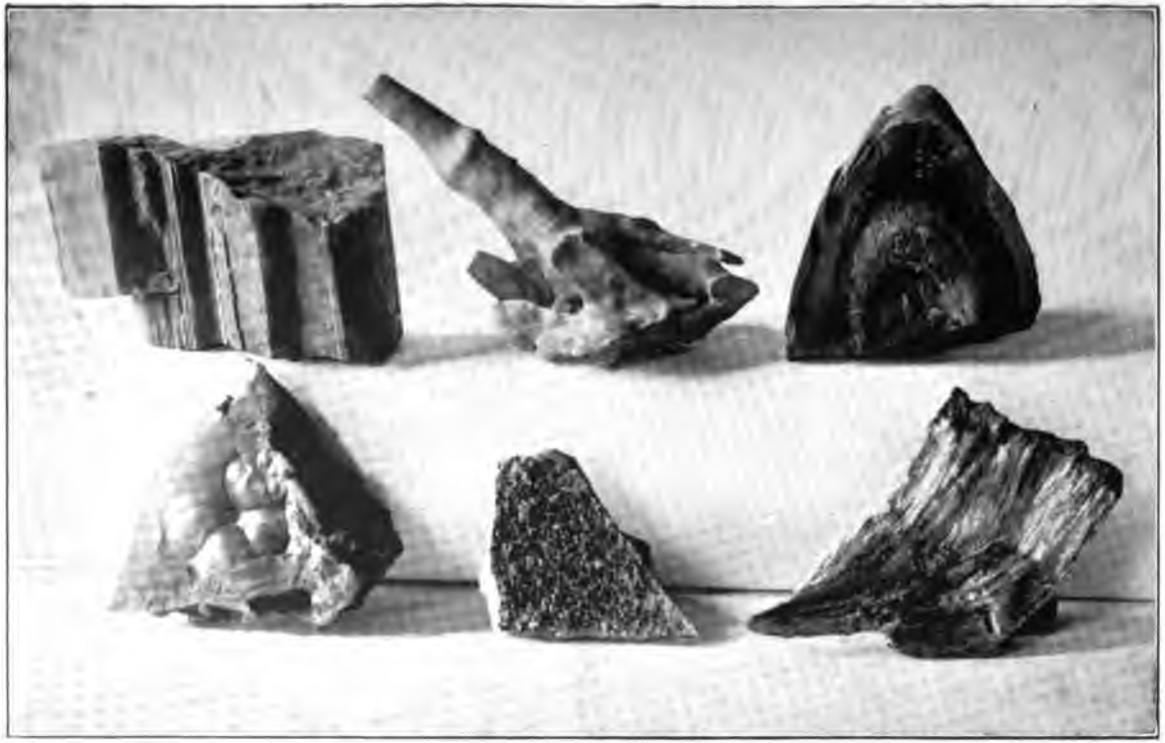

PLATE II: Structure.
Columnar Beryl,
Harney Peak.
Reniform Chalcedony,
Badlands.

Stalactitic Calcite,
Jewel Cave.
Pyrolusite Dendrites,
Lead.
(⅓ natural size.)

Calcite Concretion,
Badlands.
Fibrovs Asbestos,
Rochford.

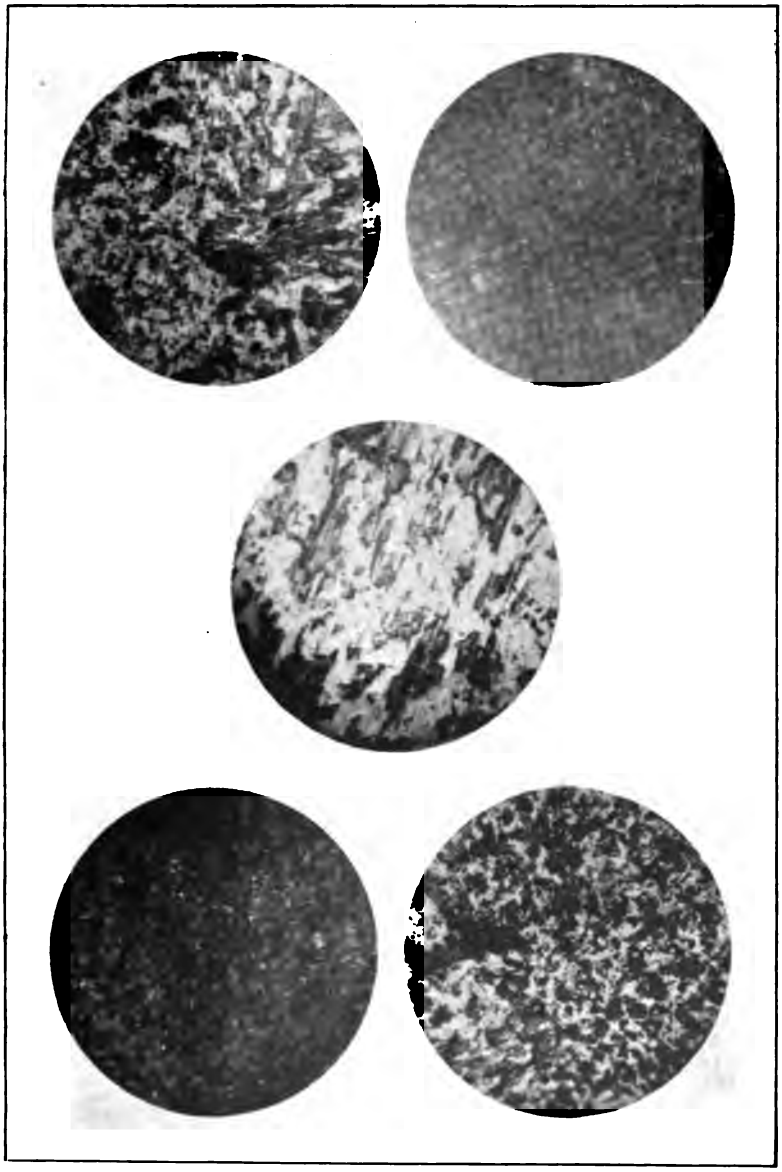

PLATE III: Microstructure of Lead-antimony Sulphides,
Silver City (33.6% Pb.) Hill City (28.3% Pb.)
Silver City (44.68% Pb.)
Calaboga (66.25% Pb.) Hill City (34.74 % Pb.)

thickness and hence is a rock. Thus the main distinction to be carried in mind regarding the choice of the word "rock" or "mineral" is the idea of abundance. It is also true that by some mechanical method we can divide rocks into their component minerals. This is very frequently done, as for example when certain minerals are concentrated from a rock by jigging, or gold is freed from the gold-bearing rocks by panning. We cannot in this way separate a mineral into its component elements. A rock is then a mineral or combination of minerals making up an important part of the earth's crust.

FOSSILS.

We find imbedded in many rocks evidences of past life. These may take on various forms such as foot prints and trails, or they may be the hard parts of some animal as the shell of a clam or a snail, or the bones of the skeleton. In other cases they are only the internal casts of some shell preserved by the hardened mud-filling. To all these we apply the name "fossil." Formerly this term also included minerals and rocks, but at the present time its usage is restricted as indicated and the study of these extinct life-forms is the subject of a great science by itself—paleontology.

ORE.

The term "ore" is used very loosely among people in general and is commonly applied to almost any mineral. For the sake of accuracy, however, the use of the term is somewhat restricted in technical usage and is only applied to those rocks from which a metal can be extracted at a profit. The percentage of metal necessary to make an ore, depends on the character of the ore and on the locality of occurrence. Thus certain rocks carrying one per cent copper are ores in the Lake Superior region, while in Arizona a rock to be a copper ore must carry about four per cent.

To be an ore of iron a rock should average at least 45% in iron content, while at the other extreme a gravel bank may be "ore" if it carries twenty cents of gold per ton of rock or .00003%.

CRYSTAL.

Those of us who have visited stone quarries at some time have had our attention directed to small holes in the rocks whose walls were lined with little solids that had a definite geometrical shape terminated by smooth plane faces. Similar shapes are probably familiar to us in the form of cut glass pendants on chandeliers or in the form of precious stones. In the latter case, however, the flat planes and the geometrical shape are the work of man, while in the first case we saw them under conditions which proved that man's hand never touched them until they were exposed to our sight by the blow of the hammer. The little solids we recognize at once as minerals. The shape peculiar to them we style a "crystal." (3) Evidently this shape was formed while the mineral solidified.

The shapes of crystals are exceedingly diverse. Hundreds of different types occur in nature, giving us all imaginable forms and varying from microscopic size up to individuals forty and more feet in length. In studying hundreds and hundreds of these crystals several laws were discovered. For example, it was found that forms of the same mineral were always closely related. This is also true for artificial compounds. Thus we came to recognize that the crystal form is a definite characteristic of each particular chemical compound and that it is the result of a force acting entirely within the compound during the process of solidification. This force expresses itself by arranging the minute particles making up the chemical compound in some definite geometrical order. Mineralogists also discovered that the thousands of crystals found in nature could be divided into several groups. These groups are called crystal systems.

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(3) The term crystal is of Greek derivation and means ice. It was applied by the ancients to prisms of quartz from the Alps, which they supposed to be ice that had been hardened by the excessive cold of the Alpine winters.

CRYSTALLINE AND AMORPHOUS COMPOUNDS.

As will be evident to all, it is only under special conditions that a mineral is enabled to form a definite crystal. The minerals occurring in the Harney Peak granite are not in crystal form, but are in shape irregular grains, because during the process of soldification the different minerals interfered with each other and none had at its disposal the space necessary to form a crystal. In certain places, however, we may find small vugs or cavities in the rock and lining its wall find well defined crystals of feldspar and quartz. The open space was in existence during the time the rock solidified and hence did not limit the crystal's growth. A more familiar example is afforded by snow and ice. Both are frozen water (H_2O). Snowflakes, however, freeze in the open air, do not interfere with each other much and hence form beautiful six-sided skeleton crystals. Ice is made up of the same kind of crystals, but they are so interwoven and have interfered with each other so much, that the individual crystals are not apparent. Ice is a "crystalline" compound because it will, if the opportunity be given, form a crystal. Few compounds show no tendency to form crystals in the condition under which they solidified. These are styled "amorphous" .(Greek—without form). Evidently then in crystalline compounds the small particles making up the solid are arranged in some definite geometrical order, while in amorphous compounds there is no such arrangement. Very few amorphous minerals are known, the more common being opal, and limonite. Both minerals contain water, the first in combination with silicon di-oxide, the second, with iron oxide.

We cannot recognize the individual crystals making up the ice. How then can we tell that it is crystalline and not amorphous? In our dilemma the most refined of modern sciences come to our aid. There are many methods known in physics and chemistry which will serve to distinguish between crystalline and amorphous. Under the microscope we are able to distinguish them because the behavior of light is quite different in the two. As a further means of distinction we know that crystalline bodies have a definite melting point, i. e., they melt at a certain invariable temperature provided the pressure on the substance is constant. Thus ice always melts at 32° Fahrenheit. Below 32° it is solid, above 32° it is liquid. The same is true for all crystalline compounds and their melting points. Amorphous compounds do not have a definite melting point. Glass for example, as we heat it, gradually gets softer and softer until it is quite fluid. The more we heat it the more fluid the glass becomes. All other amorphous bodies act the same way, and none have a definite temperature above which they are liquid and below which they are solid. Other methods are available, but the above are sufficient to show the many resources and the widely different avenues of attack which man is able to utilize in the study of natural products.

MINERAL SPECIES.

Just what then are the essentials a substance must fulfill to be a distinct mineral? Keeping in mind the preceding discussion we can formulate the following definition. A mineral is a natural inorganic and homogeneous substance, of definite chemical composition and usually of a definite crystalline form.

The criteria we use for the establishment of separate mineral species are composition and form. In two specimens of the same mineral both the composition and the crystallization must be in perfect accord.

Minerals are distinct species if they have different composition and different forms, or different composition and [illegible] different

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the same form, or lastly the same composition and different forms. Thus pyrite (FeS_2) and calcite ($CaCO_3$) are distinct mineral species. On the other hand, pyrite (FeS_2) and marcasite (FeS_2), calcite ($CaCO_3$) and aragonite ($CaCO_3$) are distinct mineral species because of difference in form.

Such substances as iron sulphide and calcium carbonate which occur in more than one form are spoken of as polymorphous (poly-many). If they occur in two forms as the above, they are spoken of as dimorphous, if in three forms, as titanium oxide or aluminum silicate, they are trimorphous, etc. Frequently we get several minerals of analogous composition which crystallize in the same system and have closely similar physical properties. Such a group is called isomorphous (Iso—the same). An example is the calcite group:

Calcite	$CaCO_3$
Magnesite	$MgCO_3$
Siderite	$FeCO_3$
Rhodochrosite	$MnCO_3$
Ankerite	$CaMgFe(CO_3)_3$

Dolomite $(CaMg)CO_3$ is usually included in this group, but it has lately been proven that it does not belong here, but is a distinct mineral by itself. Many other such groups occur and will be mentioned in the discussion of minerals. A characteristic of such isomorphous groups is the fact that the minerals may occur in mixtures of any proportion and show all gradation from one member in the group to another. This will be called to mind in subsequent discussions.

Practically no mineral is ever absolutely pure, but contains impurities, sometimes as visible inclusions, and at other times so uniformly distributed and invisible, as to prove that they are present in solution like the coloring matter in red and blue glass.

II. THE FORM OF MINERALS.

As has been indicated, the different crystals occurring in nature can be divided into a series of groups. Symmetry with respect to planes is used as the basis of subdivision. A plane of symmetry is a plane that divides the crystal into halves that bear the same relation to each other as an object bears to its image in the mirror. It is necessary then that the halves be of identical size and shape. The more such planes a crystal possesses the higher its degree of symmetry. Broadly speaking, all crystals fall in one of the following groups:

1st System, includes those with 9 planes of symmetry.
2d System, includes those with 7 planes of symmetry.
3d System, includes those with 5 planes of symmetry.
4th System, includes those with 3 planes of symmetry.
5th System, includes those with 1 plane of symmetry.
6th System, includes those with 0 plane of symmetry.

It is possible then to cut certain crystals into identical halves along nine different planes, while others can in no way be so divided.

CRYSTAL AXES.

It has been found very convenient to put certain imaginary lines through the center of each crystal to which we can refer the different faces. These lines we call crystal axes. Three are usually taken, in one system four. The relative length and inclination of these axes differ in the the various systems, and according to this relationship the systems are named as will be emphasized in the succeeding dicussion.

THE ISOMETRIC SYSTEM.

The first system is composed of crystals ordinarily having nine planes of symmetry. In this case the crystal axes are three lines at right angles to each other and equal in length, hence the name "isometric" (equal length). Figs.

1 to 18 show characteristic simple forms of this system with their crystal axes. To see that these solids possess nine planes of symmetry is often difficult for persons not accustomed to thinking in three dimensions. These planes will be easily recognized if we cut a cube out of a potato and determine in how many ways we can cut it into similar halves. Looking down on the top, we readily see that we can cut it into symmetrical halves along either diagonal of the square face and also along a line from the center of the back edge to the center of the front edge. This gives us three planes. Looking at the front face of the cube, we see that we can again cut it parallel to the two diagonals, and in addition from the center of the right hand edge to the center of the left hand edge. This makes six planes. Last we look along a side face and cut along its diagonals, and also from the center of the upper edge to the center of the lower edge. This gives us our total of nine planes of symmetry. Their placing on the other crystals is exactly the same.

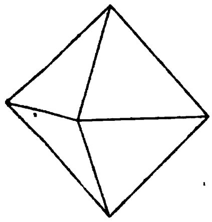
Fig. 1. Octahedron.

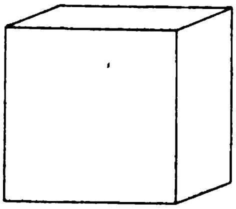
Fig. 2. Cube.

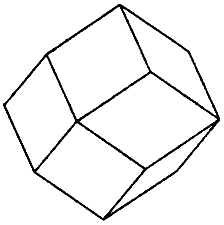
Fig. 3. Dodecahedron.

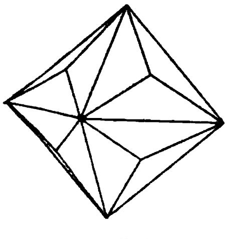
Fig. 4. Trisoctahedron.

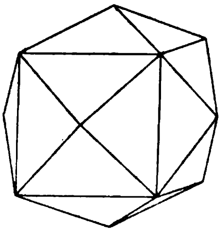
Fig. 5. Tetrahexahedron.

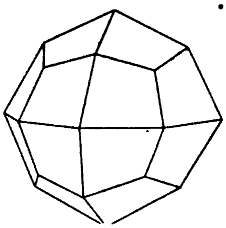
Fig. 6. Trapezohedron.

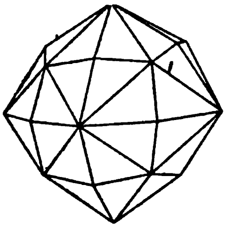

Fig. 7. Hexoctahedron.

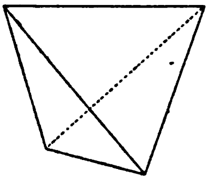

Fig. 8. Tetrahedron.

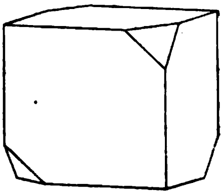

Fig. 9. Tetrahedron and Cube.

LIST OF FORMS OF THE ISOMETRIC SYSTEM.

1. The Cube, a solid bounded by six square faces.
2. The Octahedron, (octa-eight, hedron-planes), a solid bounded by eight triangles whose sides are equal and which on that account we call "equilateral."
3. The Dodecahedron (dodeca-twelve), a solid bounded by twelve rhomb faces. Each face looks like a square whose top has been pushed sideways.
4. The Trisoctahedron (tris-three), a solid made up of twenty-four faces arranged in sets of three. Each face is an isosceles triangle (i. e. two of its sides are equal). In general its shape suggests an octahedron.
5. The Trapezohedron, a solid made up of twenty-four trapezoid faces (i. e. each face has four sides, all unequal, but two are parallel). They are in sets of threes. This solid also suggests an octahedron in shape and is often called the tetragonal (four sided) trisoctahedron.
6. The Tetrahexahedron (tetra-four, hexa-six), a solid bounded by 24 isosceles triangles arranged in sets of four. In general shape it suggests a cube (hexahedron).
7. The Hexoctahedron, a solid bounded by forty-eight scalene triangles (i. e. none of their sides are equal). They are arranged in sets of six. In shape this solid also suggests the octahedron.

Every one of these solids is symmetrical with respect to nine different planes, and we can place into each one three crystal axes at right angles to each other and equal in length. We also include in this system certain forms which do not have the full nine planes of symmetry, but do have three equal axes at right angles. These forms we call hemihedral (half forms). Their form is difficult to understand; they are not common and for these reasons only two will be mentioned here.

1. The Tetrahedron, bounded by four isosceles triongles.

2. The Pyritohedron (named after the mineral pyrite), bounded by twelve pentagonal faces.

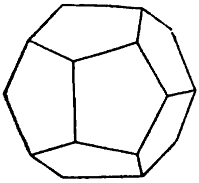

Fig. 10. Pyritohedron.

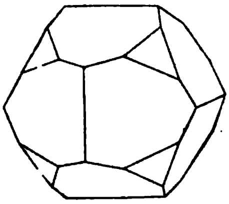

Fig. 11. Pyritohedron and Octahedron.

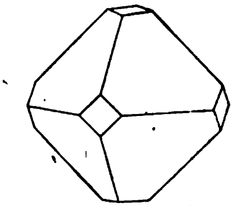

Fig. 12. Cube and Octahedron.

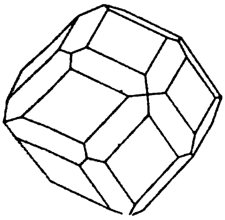

Fig. 13. Dodecahedron and Trapezohedron

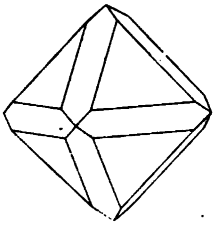

Fig. 14. Octahedron and Dodecahedron.

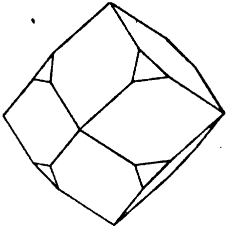

Fig. 15. Octahedron and Dodecahedron.

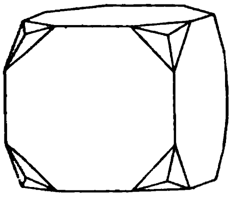

Fig. 16. Cube and Trapezohedron.

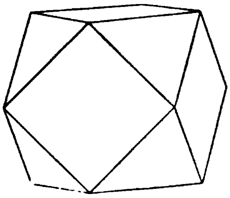

Fig. 17. Cube and Octahedron.

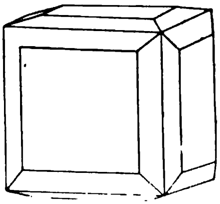

Fig. 18. Cube and Tetrahexahedron.

If more than one of these forms is present on a crystal, which is commonly the case, we apply the term "combination." Figs. 9-18 show such combinations in the isometric system.

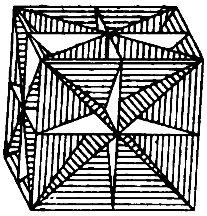

Fig. 19. Planes of Symmetry in a Cube.

Notice that in every case we have the full symmetry preserved and still have the three equal crystal axes in their original position.

THE HEXAGONAL SYSTEM.

The second system is characterized by having seven planes of symmetry. This system requires four crystal axes, three in one plane making angles of 60° with each other and the fourth at right angles to this plane at their intersection. The common arrangement of faces gives us six angles around the circumference, hence the name hexagonal. The seven planes of symmetry are readily apparent in Fig. 26.

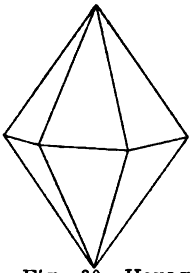

Fig. 20. Hexagonal Pyramid.

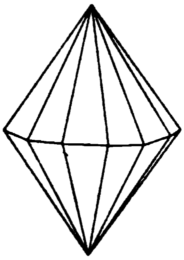

Fig. 21. Dihexagonal Pyramid.

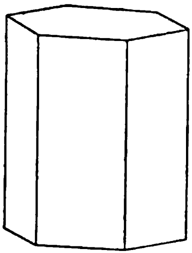

Fig. 22. Hexagonal Prism with Basal Pinacoid.

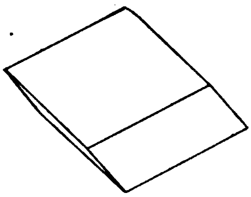

Fig. 23. Rhombohedron.

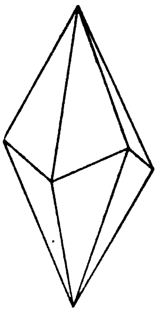

Fig. 24. Scalenohedron.

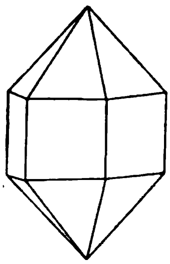

Fig. 25. Hexagonal Prism and Pyramid.

The forms of this system are as follows:

1. **Pyramids, these are bi-pyramids (bi-two) that are bounded by twelve isosceles triangles, six on top and six below the base. There may also be twelve faces above and twelve faces below when the name dihexagonal (di-double) pyramid is applied.**
2. Prism, a solid bounded by rectangular faces, six in number. When twelve are present it becomes dihexagonal. The prism is terminated by some pyramid, or by a flat plane called base (or basal pinacoid) that is parallel to the three axes.

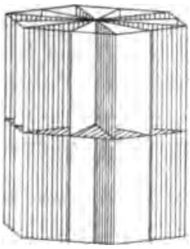

Fig. 26. Planes of Symmetry in Hexagonal Crystals.

Among the hemi-hedral forms in this system we have the following, which are very common on certain minerals:

1. Rhombohedron, a solid bounded by six rhomb faces. All faces are equal and suggest a cube that has been distorted by pushing the top along a diagonal.
2. Scalenohedron, bounded by twelve scalene triangles.
3. Trigonal Prism, a prism of three rectangular sides.

Figs. 20-25 illustrate common forms and combinations in this system.

THE TETRAGONAL SYSTEM.

The third system has five planes of symmetry. Four are vertical and intersect each other at angles of 45°, and the fifth is perpendicular to them. This system has three crystal axes perpendicular to each other. Two are of the same length and are in the horizontal plane of symmetry, the third is the line of intersection of the other four planes of symmetry. The most common forms are square in cross-section, hence the name tetragonal (four angles).

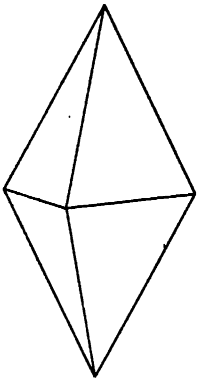

Fig. 27. Tetragonal Pyramid.

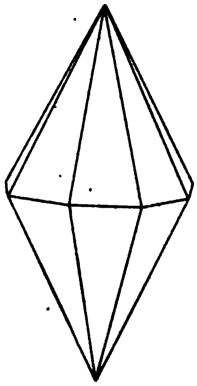

Fig. 28. Ditetragonal Pyramid.

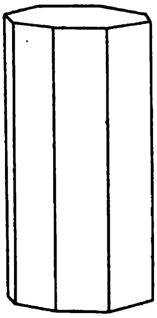

Fig. 29. Ditetragonal Prism and Basal Pinacoid.

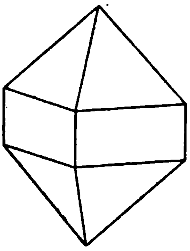

Fig. 30. Tetragonal Prism and Pyramid.

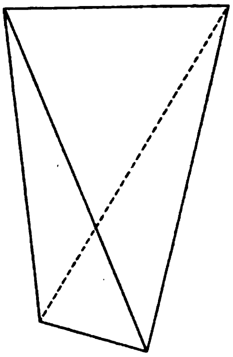

Fig. 31. Tetragonal Sphenoid.

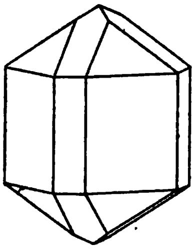

Fig. 32. Tetragonal Prisms of 1st and 2d order and Pyramids of 1st and 2d order.

The common forms of this system are:

1. Pyramids, these are also bi-pyramids and are bounded by eight isosceles triangles, four below and four on top of the base. Those with sixteen triangular faces are ditetragonal.

2. Prisms, solids bounded by four rectangular faces. They have a square cross section. A prism with eight rectangular faces is di-tetragonal. All prisms are terminated by a base or by pyramids.

See Figs. 27-32 for combinations.

THE ORTHORHOMBIC SYSTEM.

The fourth system has three planes of symmetry at right angles. The crystal axes are their three lines of intersection, which differ in length, but are perpendicular to each other. The crystals are always held with the short axis pointing towards the observer. The name orthorhombic (ortho-right) refers to the 90° (right) angles between the axes.

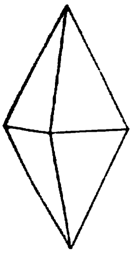

Fig. 33.

Pyramid.

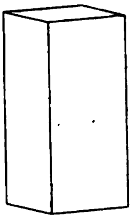

Fig. 34.
Orthohembic
Prism and
Pinacoids.

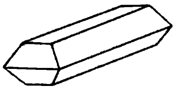

Fig. 35.
Bracchy and
Macro
Domes and
Pinacoids.

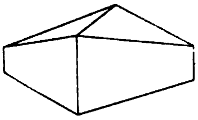

Fig. 36.
Orthorhombic
and Prism
Bracchy Domes.

The forms of the orthorhombic system are:

1. Pyramids, with eight equal triangles as faces.
2. Prisms, having four rectangular and equal faces. Prisms are terminated by basal planes and pyramids as in the hexagonal and tetragonal system, but also by domes.
3. Domes, are forms consisting of faces that are parallel to one of the horizontal axes, but intersect the other and the vertical. They are called bracchy (short) domes if they are parallel to the short (i. e. bracchy) axis, if they are par-

allel to the long axis they are macro (long) domes.

4. Pinacoids (Greek-board), are plane faces cutting one axis only. The base is often called basal pinacoid. As in domes we have bracchy and macro pinacoids.

Common combinations are shown in Figs. 33 to 36.

THE MONOCLINIC SYSTEM.

This, the fifth system, has only one plane of symmetry. It has three crystal axes, one vertical and in the plane of symmetry, a second in this plane, but making a greater angle than 90° with the first, so that it slopes down towards the observer, and the third axis perpendicular at the intersection of the first two, and hence from right to left. Since one axis is inclined the term "mono-clinic" (mono-one), characterizes this system.

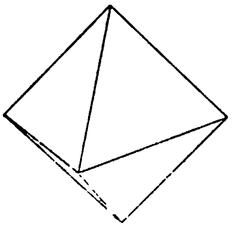

Fig. 37.
Monoclinic Pyramid.

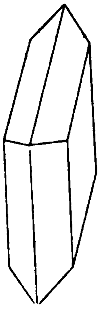

Fig. 38.
Clino Domes, Prism, and Clino Pinacoid.

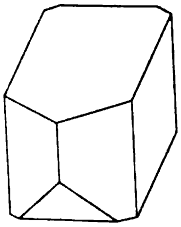

Fig. 39.
Prism, Clino Pinacoid, Basal Pinacord, and Ortho Dome.

THE COMMON MONOCLINIC FORMS.

1. Pyramids, with eight scalene triangles for faces. The two in front and those diametrically opposite, hence below and at the back, are equal, as are also the other four.
2. Prisms, with four parallelograms for faces. These are terminated as before by bases, pyramids, domes and pinacoids.

3. Domes, are called clino when parallel to the inclined axis, ortho when parallel to the ortho axis.

See Figs. 37-39 for combinations.

THE TRICLINIC SYSTEM.

This system has no planes of symmetry. The three axes are unequal in length and inclined to each other, hence the name of the system.

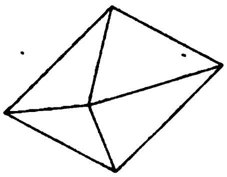

Fig. 40.
Triclinic Pyramid

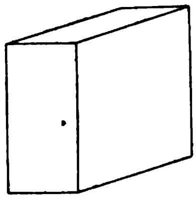

Fig. 41.
Triclinic Prism and Basal Pinacoid.

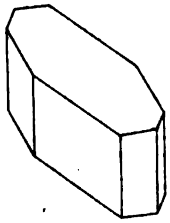

Fig. 42.
Basal Pinacoid, Prism, Bracchy and Macro Pinacoid.

The common forms:

In this system we also have pyramids, prisms, domes and pinacoids, but only the two diametrically opposite faces are equal in any case.

Crystals in this system are somewhat rare in nature.

Figs. 40 to 42 show some of the commoner forms.

SUMMARY.

In order to determine then, to which crystal system any form belongs, we determine the number of planes of symmetry it possesses. Hemi-hedral forms can be recognized by the fact that they do not have all the planes of symmetry, but do have the crystal axes characteristic of a certain system. It is important to remember that only the forms of one system can occur on any particular crystal.

TWIN CRYSTALS.

In some minerals crystals show a tendency to arrange themselves in pairs. This union is usually according to some definite rule and not haphazard. Such intergrowths we call Twin crystals.

AXIAL RATIOS.

We noted that in all crystal systems the axes had some definite relationship in length. If we measure the actual length of the axes in some crystal and express this in the form of a proportion we get the "axial ratio." This axial ratio is characteristic of each individual chemical compound, and not of the particular system in which the crystal occurs. For example the compounds $ZrSiO_4$ and $CuFeS_2$ are both tetragonal. Their axial ratios are respectively 1:1:.6404 and 1:1:.98525. The vertical axis of $CuFeS_2$ is thus fully 50% longer proportionately than the vertical axis of $ZrSiO_4$. Both have two equal axes and a third unequal one, and both have the symmetry of the tetragonal system. The axial ratio is so characteristic of the composition that a slight impurity will change it. Hence it is used by the chemist as a valuable indication of the purity of compounds.

INTERCEPTS AND INDICES.

On account of the great variety of forms occurring in nature, crystallographers have been forced to use some symbol as a name for each one. It is of course convenient to use a symbol which is characteristic and which gives some information about the form. Hence the crystallographer Weiss originated what he called the intercept, that is, an expression which showed in the form of a ratio, how far away from the center any face cut the three crystal axes. Thus, 1a:2a:1a show 1st., that the length of the unit of measure is the same on each axis, i. e., the axial ratio is 1:1:1, hence we write a a a, and 2nd., that the face cuts the vertical and forward axis at equal distances, and the sideways axis at some distance twice as great. 1a:2b:1c shows us that the axial ratio is not unity, but is expressed by three different numbers. Therefore we have a different length as a unit on each axis and the figures 1,2, and 1

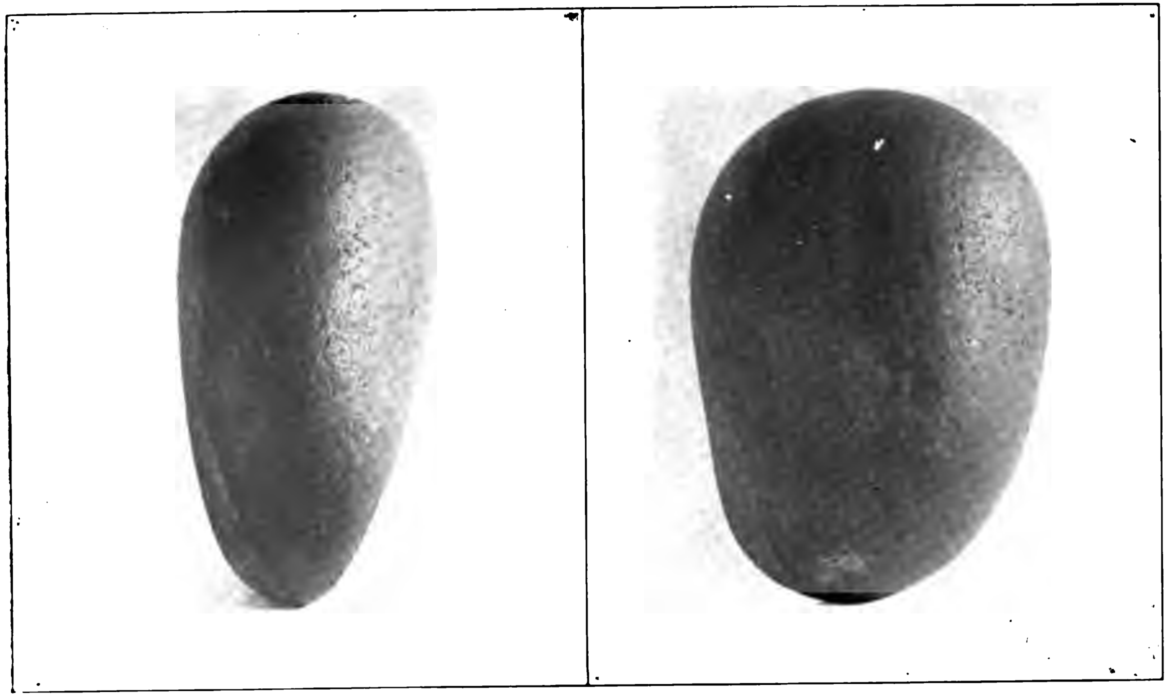

PLATE IV: Cheyenne River Iron. (Probably a meteorite.)
(Natural Size.)

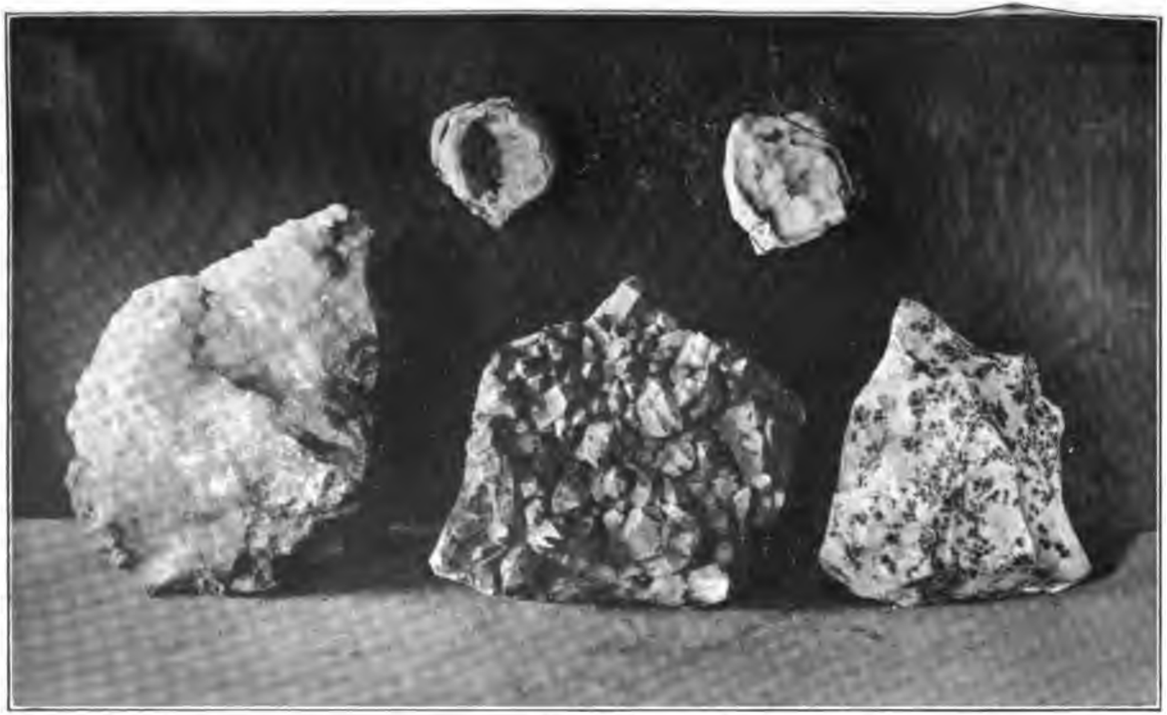

PLATE V: Quartz.

Interior of Chert Concretion,
Rapid City.

Quartz Crystals,
Harney Peak.

Moss Agate,
Laramie Co., Wyo.

On top: Quartz Geodes, Badlands. (¼ natural Size.)

show how many such units are necessary to measure the distance. In other words, then, the intercept is always the actual distance in a common unit such as inches divided by the axial ratio. In the isometric system the axial ratio is unity here 1a:1a:1a is an octahedron face because this face cuts all three crystal axes at the same distance. 1a:1a:∞a, cuts two axes at the same distance, but the third at infinity. This is a dodecahedron face. In the tetragonal system 1a:1a:1c is a pyramid; 1a:1a:3c is also a pyramid, but differs from the first. 1a:1b:1c is a pyramid face in the orthorhombic monoclinic or triclinic system, so are also 1a:2b:1c, 6a:1b:5c, etc. 1a:1b: ∞c is a prism, but 1a:3b:∞c, 3a:1c:∞c, etc., are also prisms. These figures are somewhat awkward for purposes of calculation and hence the mineralogist Miller proposed the index system. In this we leave out the letters a, b, c, showing the axes, take the reciprocals of the intercepts and clear fractions. Thus 1a:2b:1c: becomes $\frac{1}{1}$, $\frac{1}{2}$, $\frac{1}{1}$ and clearing fractions, 2, 1, 2. 1a:∞a:c becomes $\frac{1}{1}$, $\frac{1}{\infty}$, $\frac{1}{3}$ or 3, 0, 1.

The Miller system as it is called or the index is the most common in use and a few examples may make clearer the relationship between the two methods of crystal notation.

	Intercept	Index
Octahedron	1a:1a:1a	1, 1, 1
Cube	1a:∞a:∞a	1, 0, 0
Trapezohedron	1a:2a:2a	2, 1, 1
Trapezohedron	1a:3a:3a	3, 1, 1
Tetrag pyramid	1a:1a:1c	1, 1, 1
Tetrag pyramid	1a:1a:4c	4, 4, 1
Orthorh prism	1a:1b:∞c	1, 1, 0
Orthorh prism	1a:3b:∞c	3, 1, 0
Hexag. prism	1a:1a:∞a:∞c	1, 1, 0, 0
Hexag. pyramid	1a:1a:∞a:5c	5, 5, 0, 1
Rhombohedron	½(1a:1a:∞a:2c)	½(2, 2, 0, 1)

This table of a very few forms will also emphasize the fact that we have a great variety of each of the different simple forms such as prisms, pyramids, and rhombohedra.

PSEUDOMORPHS.

It very frequently happens that some mineral has been changed over by a chemical reaction into a mineral of altogether different composition without thereby losing its original form. Thus the resulting product is frequently found in a crystal form that is not a characteristic of its composition. For example we find limonite ($2Fe_2O_33H_2O$), which is amorphous, in the crystal form of the isometric mineral pyrite, (FeS_2). At times we find Cassiterite (SnO_2) which should be tetragonal in monoclinic crystals, which were originally orthoclase ($KAlSi_3O_8$). Since these crystals then are not characteristic forms due to the composition of the compound, they are called pseudomorphs (pseudo-false, morph-form).

CHARACTERISTICS OF MINERALS.

As has been indicated before, the great majority of mineral specimens do not occur in well defined individual crystals, but usually in aggregates of imperfect crystals. These may vary from those in which the individual crystals are plainly visible to others so dense that no crystal structure is apparent. The characteristic appearance of an aggregate we call structure.

STRUCTURE OF MINERALS.

1. Columnar, when its appearance suggests a series of fluted columns crowded together.
2. Granular, when it is made up of a series of grains.
3. Lamellar, when it is made up of a series of flakes or sheets.
4. Concretionary, when it is made up of layers surrounding a nucleus, as an onion is.
5. Stalactitic, suggesting in shape an icicle.
6. Stalagmitic, in shape like the ice formed by water dripping off the icicle and freezing on the ground below.
7. Dendritic, tree-like in shape.
8. Botryoidal, suggesting a bunch of grapes.
9. Reniform, kidney like in appearance.
10. Acicular, hair-like or needle-like.

CLEAVAGE.

Many crystalline compounds show a decided tendency to part or cleave along definite planes. It is almost impossible to break a piece of calcite ($CaCO_3$) and obtain a rough irregular surface, i. e., a "fracture." Usually we get a perfect division along plane surfaces, i. e., a "cleavage." Cleavage serves as an important factor in the identification of minerals because it is exhibited in varying degrees of perfection by different minerals. In crystals it is usually named according to the particular face it is parallel to. Thus galena (PbS) has cubical cleavage; fluorite (CaF_2), octahedral; calcite ($CaCO_3$), rhombohedral; mica, basal.

FRACTURE.

The character of the surface obtained by a break aside from the cleavage is often of value. There we apply terms that are self-explanatory such as rough, splintery or conchoidal (with smooth curved surfaces like broken glass).

SPECIFIC GRAVITY.

Minerals vary widely in relative weights and this furnishes one of the most valuable clues for the identification of unknown specimens. For convenience we use a figure representing the relative weight of the mineral as compared to the weight of an equal volume of water. This is specific gravity. In value specific gravity ranges from about .92 for ice (H_2O) up to 21 for iridosmine (an alloy of iridium and osmium). The majority of minerals range from 2.5 to 3.5 in specific gravity. Ordinary rock has a specific gravity between 2.5 and 3 and for a rapid determination it is often sufficient to compare the weight of the mineral with the weight of a fragment of rock of about the same size, and estimating the specific gravity according to the comparative weights. If the mineral seems half as heavy call its specific gravity 1.5, if it seems twice as heavy call it six, etc. This will usually be sufficiently accurate after a little experience has been gained.

HARDNESS.

The most important of physical characteristics is the resistance a mineral offers to abrasion, i. e., its hardness. It is of great value in determining any unknown specimen. Great care must be exercised in testing for hardness that a fresh surface of the mineral is taken, and that it is free from inclusions of other minerals which may be softer or harder and are apt to lead to erroneous conclusions. Minerals have been arranged according to hardness in an ascending scale and the mineralogist Moh picked out ten of them, for a scale of hardness to which the hardness of all minerals can be referred.

MOH'S SCALE OF HARDNESS.

1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Orthoclase
7. Quartz
8. Topaz
9. Corundum
10. Diamond

If a mineral will scratch apatite, but is scratched by orthoclase we call its hardness 5.5. If it neither scratches calcite nor is scratched by it, we call it three in hardness. It is usually inconvenient to have the above minerals on hand especially in the field so hardness is determined tentatively in the following way:

1 and 2	easily scratched by the finger nail.
2.5	with difficulty scratched by the finger nail.
3	same in hardness as a copper coin.
4-5	easily scratched by a knife.
5.5	with difficulty scratched by a knife.
6	cuts ordinary glass. Is cut by extra good knife blade.
7	and above cut glass easily.

Q[redacted] abundant in nature and a piece will usually be sufficiently accurate after a little [redacted]ience.

Quartz is exceedingly abundant in nature and a piece can readily be obtained anywhere which will serve to indicate by the ease with which it is scratched the relative hardness of an unknown mineral if above 6 in the scale. For convenience we use the following terms, very soft (1-2.5), soft (3-4), hard (5-6), and very hard (7-10).

LUSTER.

The characteristic appearance of the surface of a mineral as determined by the amount and kind of light reflected from its surface, we call luster. Such terms as waxy, earthy, dull, resinous, silky, and metallic are self-explanatory. The luster of glass, we style vitreous, while the brilliant luster of the diamond is adamantine. In this connec- [illegible] is well to emphasize that the color of any mineral [illegible] tallic luster is invariant and characteristic and is [illegible] luable as a distinguishing feature.

COLOR.

As a means of distinction color is only of value in those [illegible] nerals that have a metallic luster. Minerals that are [illegible] nsparent or only slightly so, i. e., translucent, may ex- [illegible] it various colors. Thus diamonds vary in color from [illegible] v, red, green, blue, and brown to black. The [illegible] any substance possesses depends on the kind of [illegible] ts or transmits. Sunlight, as is familiar to us [illegible] up of all shades of colored lights which give as a total result the sensation of white. When sunlight is broken up, as in the rainbow or through a prism of glass, we can see these various component colors. A substance is green when it transmits or reflects to our eye only the green rays of light and absorbs the others. Commonly the color is due to a mixture of unabsorbed rays. Every shade imaginable can be found on minerals. In beauty of color they stand unexcelled. True, the sparkle of the dew drop among the bridght green gass is no less pleasing than that of the diamond gleaming among the circlet of emeralds, but in a few days or weeks at most the fresh verdant grass is wilted, while the brilliant green of the emerald will never lose its charm. To add to their beauty many gems exhibit a change of color, as for example alexandrite, which is deep green by day, but columbine red under artificial light. Who is not familiar with the gleaming and glittering spark of fire playing tag with the green and blue in the opal? The play of color shown by opal and the diamond is due to the fact that white light is broken up into its component colors in the interior of these minerals. Other minerals such as labradorite (sunstone) and also the pearl show iridescence, that is a play of prismatic colors caused by the effect of many minute cracks in the minerals. Many minerals have a color on the surface quite different from the color in the interior. This outer color is usually caused by an alteration in the chemical composition at the surface, and is called tarnish. Thus care must be exercised not to confuse tarnish with the true color of the mineral.

The color of non-metallic minerals is commonly due to some impurity present in the mineral, therefore their color is not definite. There are very few exceptions to this, as for example sulphur, which is always yellow. Chemically pure quartz (SiO_2) is white, the beautiful "rose" quartz of the Black Hills is pink due to the presence of titanium dioxide. Turquois is blue due to small amounts of copper present in the mineral. Fluorite (CaF_2) has various colors such as purple, blue, red, green, etc., due to the presence of certain organic compounds. Agates are SiO_2 in composition, their banding is due to changes in the ingredients causing the color. The colors of minerals can be changed artificially. Thus yellow topaz can be made pink by heat. Much fluorite, if heated, turns colorless. Gray and white banded agates are frequently highly colored by boiling for a number of weeks in honey or aniline dyes.

STREAK.

The color of a mineral in powdered form is its streak. We may obtain it by scratching a knife across its surface or by rubbing the mineral on an unglazed porcelain surface. This may be the same in color as the mineral or it may be different. Magnetite (Fe_3O_4) is black and has a black streak; alabandite (MnS) is black and has an olive green streak. The streaks of minerals of the non-metallic types of luster are usually white and of no value. Thus tourmaline may be brown, green, red, black, etc., but its streak is always white. In metallic minerals streak is of great diagnostic value.

SPECIAL CHARACTERISTICS.

Certain minerals have characteristics which serve as valuable hints in determining them. Such for example are magnetic properties, elasticity, malleability, ordor or taste.

THE ORIGIN OF MINERALS.

How did they get here? How were they formed? What are they made up of? These are the common questions that come to our mind when we observe the occurrence of minerals in nature. Since the origin of minerals is closely bound up with the history of rocks, the origin of these latter may throw some hints on the method of formation of minerals.

We recognize three great classes of rocks in nature, igneous, sedimentary, and metamorphic. Igneous (fire) rocks are those that have crystallized from a state of fusion. They may have been poured out upon the earth's surface through some volcanic vent like the lava of Vesuvius or of the Hawayan Islands, or the fused mass may have come to rest under the cover of overlying rocks and crystallized there into granite like that of Harney Peak, or into porphyries like those of the Northern Black Hills.

Along the shores of lakes and rivers, rocks are formed by the accumulation of sands, mud, pebbles and the shells of animals. Others are formed by the evaporation of salt lakes, and by the accumulation of plant remains. Not only water, but ice and wind are busy transporting and depositing fragmental material in favorable localities. All rocks formed in these various ways are sedimentary.

Metamorphic (meta-changed, morphic-form) rocks, may originally have been igneous or sedimentary, but they have become so changed by great pressure and heat, commonly due to burial, as to differ quite widely in appearance and maybe mineral make up from their original form. Often we can tell with a fair degree of assurance, whether a rock was originally igneous or sedimentary, but more often we are not able to state so definitely. A summary is included which may be of value in determining to which group a rock belongs.

1. Igneous Rocks:—lava flows may be glassy or look like slag, and be in layers, but as a rule these rocks are massive. Individual crystals may vary from microscopic size up to several inches in diameter. Uusually they cut across the layers of sedimentary rock.
2. Sedimentary Rocks:—Are usually in parallel and definite layers or beds. Individual beds may appear homogeneous as limestone, or be made up of sand, pebbles or mud, cemented more or less. The individual grains are rounded by wear. These rocks commonly contain fossils.
3. Metamorphic Rocks:—As a rule show a very decided and good cleavage yielding thin sheets like slate. The rock is commonly banded, showing light and dark layers. It may also be massive, when it is usually made up of irregularly interlocking fibrous minerals. Mica is a very charascteristic mineral in these rocks. In the Black Hills the metamorphic rocks commonly stand with their cleavage at a steep angle.

In keeping with the above classification we classify minerals as "primary" when they are formed from a fusion and are characteristic of igneous rocks. If they are formed in some way by the alteration or decay of the minerals of igneous rocks we call them "secondary." The quartz in a granite is primary, the quartz in a vein is secondary and younger than the rocks in which it occurs. By far the majority of minerals of economic importance have been deposited from water solutions. The water may be the ordinary meteoric water which, being charged with carbon dioxide and other acids, leaches out soluble minerals from the rocks and deposits them in favorable places, often in open fissures; or the water may be "magmatic," i. e., it may come up from fused masses of igneous rocks which are crystallizing deep beneath the surface of the earth and which during solidification expell the volatile components present such as water, boron, fluorine, chlorine, sulphur, etc., in the form of highly heated vapors and solutions. These, on account of their high temperature and high solvent power, are very active in producing chemical reactions which may yield many rare and commercially important minerals often in veins, and often in irregularly mineralized zones. Along the contact of igneous and other older rocks the character of the latter is often profoundly affected and may be completely changed. This effect we call "contact metamorphism." Formerly the changes taking place in the rocks that were intruded was thought to be due to heat alone and to a rearrangement of substances already in the rocks, but at the present time it is quite generally believed that much material is brought in from the igneous masses through solution in vapors and gases. Thus minerals may have originated in the following ways:

I. Crystallization in igneous rocks.
II. Crystallization from vapor and solution at high temperature.
III. Contact metamorphisms.
IV. Precipitation from solution at ordinary temperatures.
V. Metamorphism as a result of great pressure.
VI. Weathering.

All of the above groups are subsequently affected by weathering and many of the more resistant minerals are deposited in the fragmental sedimentary rocks. This is then simply a reworking and not a new method of origin.

B. DESCRIPTION OF MINERAL SPECIES.

In the description of minerals the classification as established in Dana's System of Mineralogy will be followed.

BLACK HILLS MINERALS.

I.—NATIVE ELEMENTS.

1. **Graphite**
2. **Sulphur**
3. **Bismuth**
4. **Gold**
5. **Silver**
6. **Copper**
7. **Iron**

II.—SULPHIDES, TELLURIDES AND ARSENIDES.

8. Stibnite
9. bismuthinite
10. tetradymite
11. molybdenite
12. galenite
13. altaite
14. argentite
15. chalcocite
16. sphalerite
17. cinnabar
18. covellite
19. greenockite
20. niccolite
21. pyrrhotite
22. bornite
23. chalcopyrite
24. pyrite
25. marcasite
26. loellingite
27. leucopyrite
28. arsenopyrite
29. sylvanite

III.—SULPHO SALTS.

30. jamesonite
31. meneghinite
32. boulangerite (?)
33. geocronite (?)
34. semseyite (?)
35. pyrargyrite
36. tetrahedrite
37. stannite

IV.—HALOIDS.*

38. halite
39. cerargyrite
40. embolite
41. fluorite
42. atacamite
43. matlockite
44. fluocerite

V.—OXIDES.

45. quartz

45a. chalcedony

46. opal
47. arsenolite
48. claudetite
49. bismite
50. tellurite
51. molybdite
52. cervantite
53. cuprite
54. zincite
55. tenorite
56. corundum (?)
57. hematite
58. ilmenite
59. spinel
60. magnetite
61. cassiterite
62. rutile
63. tapiolite
64. struverite
65. plattnerite
66. pyrolusite
67. manganite
68. limonite
69. wad
70. cuprocassiterite

VI.—OXYGEN SALTS.

Carbonates.

71. calcite
72. magnesite
73. dolomite
74. ankerite
75. siderite
76. smithsonite
77. aragonite
78. cerussite
79. malachite
80. azurite
81. bismutite

*Silicates.**

82. petalite

100. tremolite

118. tourmaline

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* (Note—Since the completion of this manuscript there have been reported to the author Cyanite (Al_2SiO_5) from gneiss, east of Custer

83. orthoclase
84. anorthoclase
85. microcline
86. albite
87. oligoclase
88. andesine
89. labradorite
90. mocroperthite
91. leucite (?)
92. nephelite
93. sodalite
94. hauynite
95. noselite
96. diopside
97. augite
98. aegerite
99. spodumene
101. actinolite
102. cummingtonite
103. hornblende
104. beryl
105. almandite
106. andradite
107. grossularite
108. melanite
109. spessartite
110. willemite (?)
111. zircon
112. topaz
113. andalusite
114. zoisite
115. epidote
116. piedmontite
117. calamine
119. staurolite
120. sapphirine (?)
121. natrolite
122. analcite
123. muscovite
124. lepidolite
125. phlogopite
126. biotite
127. ottrelite
128. chlorite
129. serpentine
130. talc.
131. glauconite
132. saponite
133. kaolinite
134. chrysocolla
135. titanite

Niobates and Tantalates.

137a. Columbite
137b. tantalite

Phosphates, Arsenates.

138. monazite
139. purpurite
140. triphylite (soda)
141 lithiophylite
142. heterosite
143. apatite
144. pyromorphite
145. vanadinite
146. triplite
147. griphite
148. amblygonite
151. dufrenite
149. olivenite
150. kehoite
152. vivianite
153. scorodite
154. arsenostrengite
155. cacoxenite
156. torbernite
157. autunite
158. uranocircite
159. uraninite
160. bindheimite
161. diadochite

Sulphates.

162. barite
163. celestite
164. anglesite
165. anhydrite
166. goslarite
167. gypsum
168. melanterite
169. chalcanthite
170. kalinite
171. halotrichite
172. pickeringite
173. amarantite
174. jarosite
175. copiapite
176. wolframite
177. ferberite
178. huebnerite
179. scheelite
180. wulfenite
181. cuprotungstite

VII.—HYDRO CARBON COMPOUNDS.

Petroleum, coal, retinite, asphaltum.

I. THE ELEMENTS.

The elements are divided into two classes, metals and nonmetals. The physical characteristics of the two groups

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and Cryolite (Na_3AlF_6) from pegmatite near Glendale. The latter occurrence is doubtful. No specimens are available for description).

are quite distinct. The metals are malleable, are good conductors of heat and electricity, and are opaque. Non-metals have none of these properties, they are brittle if solid, often transparent, and are poor conductors of heat and electricity. A third group includes certain elements that have the properties of metal imperfectly developed and are hence called semi-metals or metalloids. Gold, silver and iron are metals; sulphur, oxygen, and carbon, non-metals; and antimony and bismuth, semi-metals. The following elements have been found in the native state within the Black Hills region:

Non-metals:
  Graphite (C) crystallied carbon.
  Sulphur (S).
Semi-metals:
  Bismuth (Bi) ?*

*Samuel Scott in "Rocks, Minerals, and other Resources of the Golden Black Hills, etc." (1897) also mentions Tellurium Antimony and Arsenic. Their occurrence is more uncertain than that of Bismuth.

Metals:
  Gold (Au)
  Silver (Ag)
  Copper (Cu)
  Iron (Fe) (meteoric)*

*Mercury and lead have also been reported, but their occurrence has not been substantiated.

1. GRAPHITE (C) (also called Black lead and Plumbago).*

The only form of carbon found in the Black Hills is graphite, which is in the hexagonal system. Well formed crystals of graphite are not known from the Black Hills, except some of minute size. It usually varies from lamellar or scaly cleavable masses to porous finely granular aggregates. The first form has commonly a bright metallic luster, the second is dull. The color varies from a dark steel gray to iron black and the streak is dark lead gray and shiny, like the streak of a lead pencil. Graphite is opaque and has a greasy feel. It is very soft and readily scratched by the finger nail. It is very light (2.09 to 2.23 in specific gravity), and rubs off on the fingers. The name comes from the Greek, signifying to write and alludes to the use of graphite (Black lead) in the manufacture of lead pencils. It is readily confused with molybdenite (MoS_2), but may be distinguished by rubbing over a glazed porcelain when the streak left by the molybdenite is quite greenish, while that of the graphite is lead gray. Graphite is made to quite an extent artificially, at Niagara Falls for example. It is used for "lead pencils," stove polish, crucibles, lubricants, electrical purposes, and out-door paints. Graphite chiefly occurs in the metamorphic rocks of the Black Hills in the vicinity of Rochford, Mystic and Custer. Graphite slates are abundant. In these rocks the graphite has undoubtedly originated through the distillation of organic matter which was buried with the metamorphosed sedimentary rocks. Graphite of similar origin occurs in quartzite on French Creek in granular masses of varying purity up to one foot in thickness.

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*Carbon occurs in nature in several forms. When in the isometric system it is diamond. Diamonds are usually associated with igneous rocks of basic character or with the detrital material formed by their alteration. High pressure and high temperatures seem to be necessary factors in the formation of the diamonds. Their origin, however, is not fully understood. It is the hardest substance known.

In the Southern Hills it is found in considerable abundance in quartz veins in almost microscopic rosette-like aggregates. It also occurs in the same way in the quartz of some pegmatites. Some of this graphite was undoubtedly derived from the carbonaceous rocks that were cut or intruded, but in the cases of some of the pegmatites, especially those cutting the granites only, the carbon was probably an original constiuent of the magna, i. e., the fused igneous rock before crystallization.

Several of the tin-bearing granitic dikes and the pegmatites of the Harney Peak district show at the contact with the intruded metamorphic rock a well enriched zone of graphite (96) several inches in thickness, usually associated with many small tourmaline needles and a little cassiterite. This graphitic zone extends at times a few feet into the intruded rock, here a schist, and is undoubtedly of true contact metamorphic origin, owing the graphite enrichment to concentration of carbon from the surrounding rocks by the hot vapors and solutions from the igneous intrusive.

Attempts have been made to produce graphite on a commercial scale, but the percentage of impurities present has made it unprofitable so far.

2. SULPHUR (S).

This element crystallizes in the orthorhombic system and usually in well defined pyramids that are often modified by basal planes. They are resinous in luster, bright sulphur yellow in color and are transparent. They are very soft (1.5-to 2.5) and light (specific gravity 2.06). In the Black Hills no crystals have been found, but only a yellow pulverulent residue of sulphur left in cavities of the Pre-Cambrian rocks, or as a coating on decomposing shale dumps. Here it is formed by the decomposition of pyrite (FeS_2) and gypsum ($CaSO_4.2H_2O$). In the same form it occurs sparingly in the weathered portions of the coal-bearing shales in the vicinity of Aladdin. It is also found near Rochford and Hayward. In the powdery form it is very light and earthy in appearance. It burns readily, melting first, with a blue flame and with a characteristic choking odor. This serves to distinguish it from all other minerals. It is not found in the Black Hills in sufficient quantity to be of economic importance. In Louisiana and in Sicily sulphur occurs in immense beds and these furnish the greater part of the world's output. It is used widely in the manufacture of rubber goods, matches, gun powder, sulphuric acid, disinfectants, and medicine. Much of the sulphur so used is derived from pyrite (FeS_2) or is recovered as a by-product in different metallurgical plants.

3. BISMUTH (Bi).

This element usually occurs in isolated grains of metallic luster or in tree-like branching forms winding between the minerals of a rock. It is silver white in color and streak with a slightly reddish tinge, but is usually tarnished. Bismuth is brittle, very soft (2-2.5), and very heavy (specific gravity 9.8). It melts very easily. It is used in alloys such as type metal, also in medicine, calico printing, and porcelain manufacture. Scott× (44) mentions it is occurring sparingly in several quartz veins near Keystone. Bismuth also occurs in the vicinity of Hill City, on the Annie No. 1 claim.

4. GOLD (Au).

Gold is one of the most widely distributed elements in nature. It occurs under a great variety of conditions, but is almost invariably associated with quartz and pyrite. In small traces (from 5—11 milligrams of gold and from 20—169 milligrams of silver per ton) it is found in ocean water. The total will run into the thousands of millions of tons. It is sparingly distributed in traces in all types of rocks, in quartz veins, and in gravels. Due to this widespread occurrence in the native state it was known to the most ancient races of history and used as a medium of exchange and for ornaments. Cups, diadems, bracelets, earrings, gold beads and other ornaments contained in a silver vase were recently discovered during excavations on the site of ancient Troy and are believed to date back at least as far as 4000 B. C. Great skill and excellent technique are shown in the engraving on these ornaments. Gold was known to the ancient Egyptians, Assyrians, Babylonians and Hebrews as well as to the Greeks. It owes its universal favor to the fact that it is very resistant to the common acids, that it is soft and very malleable, and that its pleasing color will not tarnish under ordinary conditions. In addition to its native form, gold occurs in nature in only one compound, as a telluride. It is known in both forms in the Black Hills, although the occurrence of the telluride was for some years disputed. Gold was first discovered in the Black Hills in 1874 by H. N. Ross and W. T. McKay, miners accompanying the expedition of General Custer. The place of discovery was within the town of Custer in the gravel of French Creek.* From the mineralogical standpoint gold occurrences in the Black Hills are classified as follows:

1. Tellurides.
2. Native gold:
    - (a) Occurring in place
        - I. In veins.
        - II. In mineralized zones in metamorphic rocks.
        - III. In sedimentary rocks (in sand stones, conglomerates, shales, lime stones, and coal).
        - IV. In igneous rocks and pegmatites.
    - (b) Occurring in gravels.
        - I. "dry" placers.
        - II. "wet" placers.

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*For a historic account of the discovery of gold and a discussion from the mining standpoint the reader is referred to Bulletin No. 6, South Dakota State School of Mines, "The Mineral Wealth of the Black Hills," by Dr. C. C. O'Harra. (65)

The gold tellurides are compounds of gold and tellurium, usually containing some silver. The more important varieties are discussed under sylvanite, as is also their occurrence in the Black Hills.

Native gold is always alloyed with some silver and sometimes with traces of copper and iron. Very rarely palladium, bismuth, and rhodium are also present. It crystallizes in the isometric system in octahedrons and dodecahedrons especially, but it usually occurs in flattened grains or scattered flakes, and small masses, or in tree and fern-like growths. Crystals are not known from the Black Hills, except that several small flakes with crystalline surfaces are mentioned by Sharwood (103) and by Irving (74). It has no cleavage and is very malleable. Gold is 2.5—3 in hardness and therefore very easily scratched by a knife. The streak is golden yellow and shiny, becoming lighter in color with an increase in the silver content. Gold, high in silver, and hence pale in color, has been called electrum since the time of Pliny. Gold derived from the oxidation of tellurides, is often very dark brown to rusty in appearance, but will turn bright if highly heated. Gold is very heavy, varying from about 16—19 in specific gravity, depending on the percentage of silver. It is readily distinguished from chalcopyrite and pyrite (which see) by its softness, malleability, streak, and specific gravity. The following analyses of Black Hills gold show variations in composition:

	Parts per 1000		
	Gold	Silver	Impurities
Homestake	824	162	14
Deadwood Gulch	907	93	
Rapid Creek	940	60	
Spring Creek	934	49	16
French Creek	933	55	12
Highland	820	170	10
Terra	825	160	15
Deadwood	850	140	10
DeSmet	820	170	10

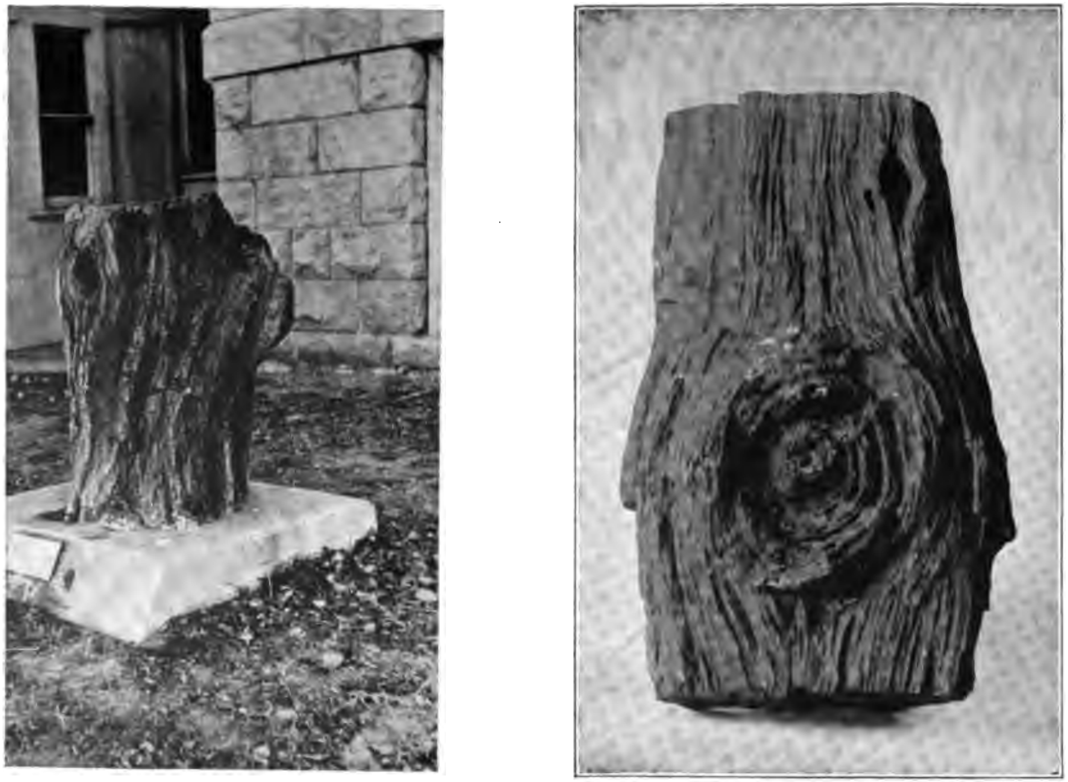

PLATE VI: Silicified Wood,
Rapid City.

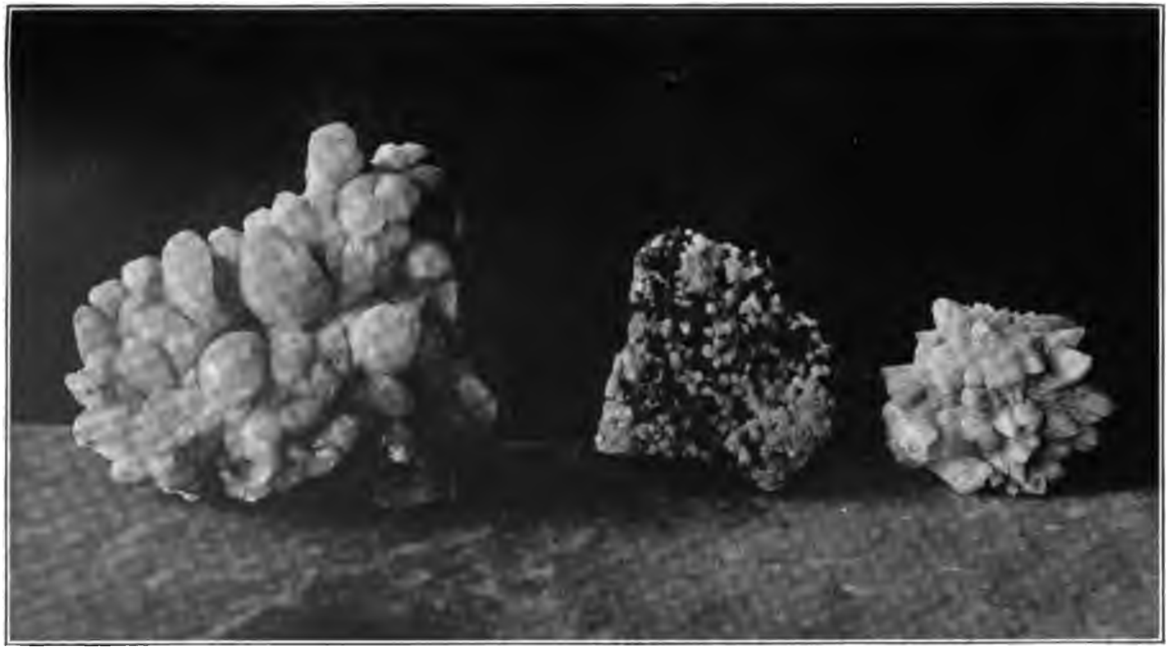

PLATE VII: Calcite.

Scalenohedrons,
Jewel Cave.

Rosettes of Rhombohedrons,
Lead.
(2-5 natural size.)

Scalenohedrons,
Jewel Cave.

			Parts per 1000		
			Gold	Silver	Impurities
Homestake*	surface	coarse	831.0	169	trace
		medium	823.0	177	trace
		fine	819.5	176.2	4.3
	400, 500 and 600 level	coarse	849.0	151.0	trace
		fine	823.0	173.3	3.7
	1000 and deeper	coarse	841.0	158.8	.2
		fine	823.0	166.8	10.2
	average of 1 week's panning from all parts of the mine	coarse	840.0	151.0	9.0
		fine	813.5	164.7	21.8
	Highland ore body	coarse	830.0	165.5	4.5
		fine	823.0	169.0	20.0
	Caledonia	coarse	827.0	169.0	4.0
		fine	818.0	171.5	10.5
	Pierce, coarse and crystalline flakes		802.5	160.5	37.0

When occurring in quartz veins gold is usually associated with pyrite, (FeS_2) or arsenopyrite ($FeAsS$). These two minerals when exposed to the atmosphere are readily decomposed yielding limonite ($2Fe_2O_3.3H_2O$), which causes a rusty staining and cellular structure in the quartz. Quartz veins are abundant in the area of the Pre-Cambrian rocks. The quartz is usually milky, and pyrite is restricted to deeper workings. They occur near Custer, Keystone, Rochford, Terry and Hill City. The largest masses of gold found in place in the Black Hills come from these veins. In mineralized zones in the metamorphic rocks the gold is usually in shists rich in chlorite, cummingtonite, actinolite, tremolite and quartz. Arsenopyrite, pyrite, and pyrrhotite are also present. Near the surface these iron minerals have been oxidized and hence the ores are rusty and reddish brown. Lower down, however, these minerals are fresh and the ores are predominantly green in color. The chloritic material is often spoken of as talc by the miners, while to the cummingtonite, actinolite and tremolite they apply the name hornblende. Ores of this general character occur in the vicinity of Lead and Deadwood, in the so-called Homestake Belt, also near Rochford and Mystic. The gold usually occurs in small thin flakes in the chlorite. Ores carrying arsenopyrite tend to go above the average in gold content. Gold ores are also found in the sedimentary rocks of the Hills, especially in the rocks of Cambrian and Carboniferous age. The basal conglomerates of the Cambrian (i. e., the Deadwood formation) furnishes the so-called cement ores. These may be old placers, as has been argued by some (3), but it is also probable that important subsequent enrichment has taken place (65). The cement ores vary from conglomerates to coarse sand-stones or quartzites. Usually only the lower few feet are productive. The gold occurs in small rounded particles, often tarnished by a coat of iron oxide. This type of ore was first mined in 1876 west and southwest of Deadwood. It also occurs in Deadwood Gulch, Spring Gulch, Rockerville, and Bobtail Gulch. Free gold is also found in the shales and sandstones of the Cambrian on Spearfish Creek, and near Crown Hill and Rockerville. The gold ores occurring above the cement ores of the Cambrian, often referred to as "siliceous," are described under sylvanite, as are also the carboniferous ores.

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*The following analyses of Homestake gold are a few from a table given by W. J. Sharwood, "Analyses of some Rocks and Minerals from the Homestake Mine, Lead, S. D.," Ec. Geology Vol. VI., pp. 730-789. All other analyses are quoted from Bulletin No. 6, South Dakota State School of Mines.

A rather unusual occurrence of gold and hence worthy of notice, is the one cited by Stone (109), viz. an association of gold and coal in the Cambria, Wyo., district. An assay of the ashes of this coal gave results of $10.00 per ton. This led to the further investigation showing the sandstone roof of the coal strata to carry $2.00 gold per ton. Samples from thirty-one cars of coke were taken during a period of three weeks in 1896, which gave an average result of $2.46 per ton in gold and $0.28 in silver.

Stone comes to the conclusion that the gold was brought in with the sand and grit which occur above the coal, and that while the sand was being deposited, the gold worked down into the underlying bog which was subsequently metamorphosed into coal.

As the rocks of the Pre-Cambrian and younger areas were exposed for ages to the action of the atmosphere they were attacked by the oxygen and carbon dioxide in the air, by changes in temperature and by the falling rain and the driving winds. Thus the solid rocks were broken up into fragments and converted into gravel and soil. By ceaseless activity the water from rain falls and that in the streams washed away much of the loose material. The larger blocks and the heavier material could only be transported by the swiftly moving streams. The constant shifting and rolling to which the loose material in the bottom of the streams was subjected tended to aid the heavy minerals to sink to the bottom and so become concentrated. Thus we find the heavy material in streaks and pockets in the depressions in the creek bottoms wherever there was a tendency to check the velocity of the stream flow. These concentrations of heavy minerals we call placers. As will be evident from the analyses on page 27, the gold in placers is of greater purity than gold found in place. This is due to the fact that silver is more easily soluble and so is partly removed during weathering. The following description is taken from Dr. O'Harra's "Mineral Wealth of the Black Hills." "Associated with the gold in the placers are garnets, hemitite and limonite pebbles (slickers), columbite, tantalite, cassiterite and other less noticeable minerals. The garnets are abundant in most of the streams, particularly those of the central and southern Hills. Columbite and tantalite are not uncommon in the Harney Peak district. Cassiterite occurs in pretty much the same streams as the columbite and tantalite, it being found in such abundance in the Nigger Hill gulches as to have furnished considerable annoyance to the miners before its nature was learned." Much of the gold is in fine particles, although considerable coarse gold has been found in Castle and Battle Creek and in the Nigger Hill district. The following record of the largest nuggets is partly taken from Dr. O'Harra's bulletin, op. cit.×:

Date.	Value of Nugget.	Finder.	Locality.[*]
1875	$18.00	Portigee Frank	Discovery Claim, Bear Gulch
1875	23.00	Unknown	Montana Bar, near Sheridan
1876	51.00	John McTigue	Claim 32, Bear Gulch
1876	146.00	Frank Mantz	Claim 28, Potato Gulch
1877	57.00	E. St. John	Claim 23, Bear Gulch
1877	90.00	Frank Mantz	Claim 12, Potato Gulch
1877	56.00	E. St. John	Claim 31, Bear Gulch
1878	81.00	John Majors	Mallory Gulch
1878	120.00	Peter Thorson	Centennial Gulch
1879	465.00	Doc Wing	Claim 37, Bear Gulch
1879	54.00	David Gillespie	Claim 16, Bear Gulch
1881	78.00	William Bell	Sand Creek
1882	51.00	E. St. John	Claim 12, Bear Gulch
1883	117.00	M. R. Hydcliff	Mallory Gulch
1884	80.00	Ed. Nelson	Palmer Gulch
1887	53.00	Jas. McCoun	Claim 5, Bear Gulch
1890	27.00	Samuel Moll	Ruby Gulch
1893	63.00	M. R. Hydcliff	Sand Creek
1893	57.00	Messrs. Heavirlau & Mulheisen	Poplar Gulch
1899	43.00	Lee & Chas. Carr	Lightning Creek

The best known placer districts of the Black Hills are Deadwood Gulch, Whitewood Gulch, Gold Run Gulch, Black Tail Gulch, and Bobtail Gulch near Deadwood; Bear Gulch, Potato Gulch, Nigger Gulch, Sand Creek, Poplar Gulch, and Mallory Gulch in the Nigger Hill district; and a high terrace near Rockerville. Recently a large dredge has been in operation near Mystic on the gravel of Rapid Creek. Gold has also been reported from several localities in the Bad Lands in placer form. In a few scattered localities the gravels run about forty cents per ton in the richest portion, but no permanent water supply is available for their exploitation.

Gold is the most important mineral product of the Black Hills region, last year's (1912) production amounting to $7,734,800, while the total production since its first discovery will exceed $180,000,000.

5. SILVER (Ag-Argentum).

Usually has the characteristic silver white color with shiny metallic lustre on fresh surfaces, but on exposed surfaces is tarnished black, due to the formation of a sulphide of silver (Argentite Ag_2S). It is very soft (2.5-3) and very heavy, the specific gravity varying from 10 to 11. It is commonly alloyed with gold, or copper, also sometimes with platinum, antimony, bismuth and mercury. The crystals, which are scarce, belong to the isometric system, but usually we get coarse to fine masses of flat tree-like or fern-like appearance. Often it is in curved wire like form or even hair-like. Silver is characterized by its color, streak, softness, and malleability. Scott (44) mentions it as occurring in the mines at Galena and Spokane, but no specimens are at hand for study.

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[*] The largest nuggets that were ever found were the "Welcome Stranger," containing 69.67 kg. (approximately 143 lbs.) gold, the "Welcome," containing 65.16 kg. (approx. 143 lbs.) gold, the "Blanche Barkly," with 54.24 kg. (approx. 119 lbs.) of gold. All were found in Victoria, Australia.

6. COPPER (Cu-Cuprum).

Together with gold and silver, it is one of the oldest known metals. In native form it has a widespread occurrence, but the most famous deposits are those on Keweenaw peninsula, on Lake Superior. Crystals of copper belong to the isometric system, practically all of the common forms being known. Very often it occurs in skeleton crystals or in tree-like growths. Large masses are known from the Lake Superior district, some of them weighing several hundred tons. Copper is usually stained green due to the formation of a copper carbonate, malachite ($CuCO_3Cu(OH)_2$). On fresh surfaces it is a bright copper red in color. Its streak is copper red. It is 2.5-3 in hardness, and very heavy (8.8-8.9 in specific gravity). It frequently contains silver, also occasionally bismuth and mercury. Copper is a primary constituent of some igneous rocks that are low in SiO_2, for example diabase, at Keweenaw Point, in New Jersey and in Connecticut. It may also be formed by the reduction of copper compounds such as chalcopyrite ($CuFeS_2$) and cuprite (Cu_2O). Its occurrence in the Black Hills is not important. On City Creek near Deadwood native copper is found in thin films coating a graphitic schist. Here it is found associated with some pyrite and tetrahedrite. Scott (op. cit.) mentions it as occurring near Nemo, on Box Elder Creek, on Bogus Jim Creek, in the Poisoned Ox mine, near Pactola, and in the Cambrian sandstone six miles west of Fairburn. It also occurs associated with malachite, chalcocite, and cuprite in the Blue Lead mine near Sherida Sharwood (103) mentions two small specimens of copp occurring in the shallower workings of the Homestake min

A weathered somewhat shattered and recemented bla quartzite boulder found by Mr. John Moody near Haywar showed a number of fine kernels and grains of metallic copper along the weathered joint planes.

No important occurrences of native copper are kno in the Black Hills.

7. IRON (Fe).*

On plate 4 is shown a peculiar piece of iron at pre ent in the museum of the State School of Mines. This spe men was found in 1907 on one of the gravel cars of the C cago & Northwestern Railroad by Mr. Otis H. Roberts. A that time this railroad was quarrying gravel for balla from high gravel terraces of Early Pleistocene age, situat near the Cheyenne river, southeast of Rapid City. Th piece of iron lay in one of the empty gravel cars that ha just been returned for another load. It had evidently worked its way downward through the loose material on account of its greater specific gravity and escaping unloading was returned with the empty car to the quarry. It attracted Mr. Robert's attention, who was at once struck by its weight. He brought the specimen to Rapid City and turned it over to the State School of Mines.

The specimen has the perfect oval and slightly flattened shape of a stream transported boulder. It is worn smooth and is remarkably well rounded. It has the following dimensions: Maximum length 2 11-16 inches, maximum width 1⅞ inches, maximum thickness 1 5-16 inches. It is wider and thicker on one end and there the above measurements were taken. When turned over to the writer for description, the specimen had been sawed in two on one side. Probably 30 to 40 grams had been lost, the weight of the two fragments remaining being 405.4 grams. The whole speci-

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*This is only a preliminary description, as complete chemical analyses of this iron are not yet available. A thorough discussion will appear within the next few months.

NO	VII. THESE MINERALS HAVE A TASTE.
, Sp. Gr.	**Melanterite** $FeSO_4.7H_2O$. H=2, Sp. Gr.=2, greenish to white effervescent. Harsh, sweet, astrin-

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presence of a soluble constituent such as cementite (Fe_3C) or it may be due to the fact that the iron is more readily soluble along the edges. The structure is very similar to that shown in fig. 66F of Howe's (H. M.), "Iron, Steel and other Alloys," which is a polished section of a steel carrying 1.20% of carbon. Meteorites possessing a structure such as this are grouped under the term ataxitic. All such meteorites as are cited by Farrington, are characterized by high nickel content, none going below 4.18% in nickel.

In summary we may say:

1st. That the conditions under which the iron was found suggest a prehistoric age.

2nd. That its shape is due to wear caused during water transportation, presumably in the early part of the pleistocene period.

3rd. That since its deposition, the Cheyenne River cut down its valley several hundred feet below the gravel terrace in which it occurs.

4th. That the length of time necessary for its burial renders improbable any chance of artificial origin.

5th. That its physical characteristics, viz. its softness and malleability do not accord with its high carbon and silicon content.

6th. That there is nothing in its composition to account for its rust-resisting properties, which must be exceptional.

7th. That its chemical composition is anamalous in that the entire absence of nickel would make it the only nickel free meteorite known.

8th. That the iron shows no crystalline structure and belongs to the ataxite group.

9th. That no natural iron, as far as known, occurs in the Black Hills, and that no rocks such as are associated with native iron elsewhere, occur here.

There is one point, however, which it is well not to lose sight of. That is that the iron was not actually found in the gravel quarry, but on a gravel car. The shape, composition, physical characteristics and place of finding, however, show the almost certain improbability of its coming elsewhere. A complete quantitative analysis of the iron will probably afford additional data, and unless that should bear strong adverse testimony the author would believe the meteoritic origin the most probable explanation for the iron.

II. SULPHIDES, SELENIDES, TELLURIDES, ARSENIDES AND ANTIMONIDES.

Here we include a series of compounds made up of a metal or semi-metal and one of the following: Sulphur, selenium, tellurium, arsenic or antimony.

8. STIBNITE (Sb_2S_3).

This antimony sulphide is often present in minute amounts in the siliceous gold ores of the Northern Hills. It is present in the form of acicular to hair-like prisms, usually not more than one-half inch long, rarely thickening to about 1-32 inch and lengthening out to two inches. These usually penetrate the ore in a confused reticulated way. Occasionally a small vug shows irregularly projecting crystals as fine as a hair. The luster is bright and shiny metallic, the color is lead gray and the streak steel gray. Stibnite is soft (2) and can be scratched by the finger nail. Its specific gravity is about 4.5. The larger specimens from the Hills show perfect cleavage developed the long way of the prism and parallel to the bracchy pinacoid. On cleavage faces the luster is especially bright, and the little prisms are somewhat iridescent. Stibnite occurs in the Northern Hills in the gold ores of the Deadwood and the carboniferous formations, on Bald Mountain, Whitetail Gulch, Nevada Gulch and Yellow Creek. It is reported from the Southern Hills near Rochford and Silver City, where antimony is predominantly present in the ore, as jamesonite ($Pb_2Sb_2S_5$) or a related mineral.

9. BISMuTHINITE Bi_2S_3.

The only locality where this mineral has been found so far is in a pegmatite dike near Bismuth on the Cobalt claim owned by the Reinbold Metallurgical Co. The occurrence is so unusual that it deserves a full description. Exposures on the claim show a narrow pegmatite dike striking north

must therefore have weighed just about sixteen ounces
glish). The specific gravity is 7.306. It is about 4.5 in
dness, scratching fluorite with ease, and being as readily
atched by apatite. The surface is smooth, of a dark choc-
ate brown to brownish black color, and marked by innum-
able fine pore like pits, evidently caused by rust. The pol-
shed surfaces show that the outside rusty coating is exceed-
ngly thin, indeed it appears much like a filament of only
microscopic thickness. In one or two places, as is well
own on the accompanying plate, this rusty coating is en-
rely removed, probably due to abrasion caused during
ansportation. The absence of any important amount of
sty coating is very remarkable and shows strong rust re-
isting qualities on the part of the iron. Deposited with the
ls, which are of early Pleistocene Age, it must have
exposed for many years throughout the entire latter
of the Pleistocene age to the action of circulating
er, while previously it was transported a sufficiently
t distance to attain its well rounded shape. Such con-
ons are especially favorable to rapid rusting. Probabili-
s are so strongly in favor of the prehistoric age of this
ron, that to the author this conclusion seems inevitable.

Filings from its surface gave 94.61% iron, while drill
borings gave 94.31% iron. There are appreciable amounts
of silicon and carbon, both as graphite and as combined car-
on. In addition there is some manganese and a decided
race of magnesium. Repeated tests for nickel, cobalt and
copper proved their absence. Tests were also made for ti-
tanium, molybdenum, tungsten, vanadium, tin, chromium
and aluminum. All resulted negatively.

As to its origin one of three theories may be advanced:

1. It is meteoric.
2. It is natural, or
3. It is artificial.

No natural iron has been found anywhere near the
lack Hills region and the types of rocks (the more basic
salts), to which it appears to be restricted do
t occur anywhere in the district. For these rea-

sons the writer would eliminate the idea of a natural origin. That the iron is of artificial origin seems to be out of the question for the following reasons. Its well rounded and water-worn shape, especially argue against it. Time is necessary to wear even a chunk of comparatively soft iron into the shape it possesses. This wear must have been accomplished previous to its deposition in the gravel bank. This eliminates the entire latter part of the Pleistocene.period as the date of formation of the iron. Iron is also of so comparatively late introduction that an artificial origin seems entirely out of the question.

If the iron be a meteorite we can account for it as follows: It may have fallen while the gravel terraces along the Cheyenne River were being formed. It was shifted back and forth, worn into its present form and deposited with the other pebbles. After its burial the streams quickened their flow and the Cheyenne was enabled to cut its valley deep beneath the level of these gravel terraces.

The chemical composition and structure of meteorites are usually quite characteristic. The composition of this iron, however, is unusual for the following reasons:

1. There is nothing in the composition to account for its rust resisting qualities.

2. High carbon and silicon irons are usually very hard. This contains much graphite, but the iron is soft.

3. All meteorites listed by Farrington* show nickel and usually cobalt. There are none in this iron.

The structure of this iron as shown on a polished surface is dense and homogeneous. No crystal structure of any kind is visible even under the microscope. After etching the iron for a few minutes with iodine, and then examining it under the microscope, it assumes the appearance of an irregular mosaic of iron plates. In some of the interstices a jet black substance occurs in small, slender and often bifurcating threads. This is evidently graphite. The interstices appear to be depressed. This may be due to the and south and standing vertical. This is cut sharply in a distance of about 150 feet by nine distinct veins of milky quartz striking east and west, and dipping southeast about 60°. They will not average one foot in thickness. The contacts of these veins with the pegmatite are very sharp and smooth. All veins but one are cut off clear by the country rock (slate) at the walls of the pegmatite. One quartz vein cuts into the slate for about one foot. These veins consist essentially of milky quartz, with some muscovite and considerable graphite. This is usually in very fine flakes and weathers readily to a sooty mass. Bismuthinite occurs in the milky quartz, but not in sufficient abundance to be commercially valuable, as was shown by test runs.

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*Farrington, O. A. "Analyses of Iron Meteorites compiled and classified. Field Columbian Museum, Publication 120, Geol. Series, Vol. III, No. 8.

Bismuthinite occurs in minute acicular crystals or small foliated grains of pale lead gray color and shiny metallic luster. Weathered specimens often show a yellow tarnish. The specimens are readily scratched by the finger nail and have a pale lead gray streak. Alteration to bismite (Bi_2O_3) and bismutite $Bi_2 O_3 CO_2 H_2O$) takes place readily.

There can be no doubt of the fact that these quartz veins represent late contribution from the same magma of igneous rock that yielded the normal pegmatite dike. They seem to show that after the consolidation of the pegmatite, fissures were formed and that up through these rose the bismuth-graphite-milky quartz solutions and crystallized. Conditions were such that the country rock was able to adjust itself to the stresses and was not fractured, while the pegmatite on account of its more brittle character was unable to do so.

These veins are very similar in appearance to the wolframite veins on the Black Metal claims and elsewhere near Hill City. Barren specimens from each could not be distinguished. They show the close genetic relationship existing between these latter veins and the pegmatites of the Harney Peak region, although they are quite independent in occurrence as shown by exposure.

10. TETRADYMITE (Bi_2Te_3).

This telluride of bismuth occurs in the same associations as the stibnite. It is found in minute bladed crystals with indistinct, but prismatic outlines. The luster is brightly metallic, and the color is almost tin white. It is very soft. It is difficult to distinguish from the associated stibnite, having about the same characteristics except that its color is lighter, and the specific gravity far greater. Tetradymite has been found near Pluma, Terry, and Portland. Here it is practically free from sulphur, but gives decided reactions even in minute samples for tellurium and bismuth. Sharwood (103) mentions the occurrence of a bismuth telluride (which is probably tetradymite) associated with gold and calcite in a vug in the schists of the Homestake. Tetradymite also occurs in the vicinity of Custer associated with sylvanite and free gold, in quartz and tin veins.

11. MOLYBDENITE (MoS_2).

This mineral, to which attention has already been called in the discussion on graphite, occurs in association with the tin ores of the Southern Hills. It is evidently a primary mineral in the pegmatites and the tourmaline-mica-granites of the Harney Peak districts. It usually occurs in cleavable flakes with rough hexagonal outline. Their luster is decidedly metallic, and their color a lead gray. The mineral rubbed over a rough surface will leave a gray streak more bluish than that of graphite while on a glazed surface the mark left is quite decidedly olive green in shade. The little flakes are very soft (1-1.5) and decidedly heavier than graphite being about 4.8 in specific gravity. They are rare in the ores of the Etta Knob and in a pegmatite dike between Glendale and Hayward. Where molybdenite occurs in sufficient quantity it is of great value as an ore of molybdenum, which is used to make tough and hard steels.

12. GALENITE (PbS). (Also galena and lead glance.

This lead sulphide is the most important of the lead ores, and is quite widely distributed in nature. It crystallizes in the isometric system, cubes are especially common, octahedrons are fairly abundant. Very often a combination of both forms occurs when the octahedron truncates the corners of the cube. In the Black Hills it is often massive and occurs coarsely to finely granular. Often these masses have the cubical cleavage of galenite very well developed, showing very many bright faces at right angles to each other. The color and streak are lead gray. It is soft (2.75), and very heavy (7.2) in specific gravity). If chemically pure it carries 86.6% lead and 13.4% sulphur. Most of the galena of the Hills region carries some silver. Thus argentiferous lead ores occur near Galena, Carbonate, Iron Hill, and Spokane. Galenite also occurs near Silver City, Portland and Hayward. From the latter locality float specimens have shown 505 oz. silver per ton. It is mentioned from the Homestake by Sharwood (op. cit.) and in small amounts is fairly widespread in occurrence throughout the Black Hills. Fine galenite has been collected by the writer in the pegmatite of the Etta Knob.

13. ALTAITE (PbTe).

This very rare lead telluride occurs in the Northern Hills in isometric crystals or in small masses or fine grains with cubical cleavage. It is tin white in color, tarnishes yellow. It is very heavy (8.1 in specific gravity) and very soft. A few grains of this mineral have been found within the so-called siliceous gold ores of the Black Hills near Bald Mountain. It is also found in the Old Charley and Island Gold mines at Tourmaline, and in the gold mines near Custer, according to Scott (44).

14. ARGENTITE (Ag_2S) Silver glance.

This mineral is reported from the vicinity of Galena, Carbonate and Spokane. No specimens could be obtained or description. Usually argentite is a soft black mineral, with a bright metallic luster, a lead gray streak, and no noticeable cleavage. Crystals are octahedrons, but the mineral is usually in tree or fern-like groups, or as a coating, or disseminated as fine grains. It is sectile and cuts somewhat like wax.

15. CHALCOCITE (Cu_2S) Copper glance.

Small grains of this mineral have been found with other copper minerals in the vicinity of Fairburn, near Pactola, near Nemo, and near Sheridan. Chalcocite crystallizes in the orthorhombic system, usually in prisms terminated by basal planes, or by pyramids. Small crystals of this character come from druses in veins in the Bear Lodge district, where they are associated sparingly with other copper minerals. The grains have a decidedly greasy metallic luster, with very smooth conchoidal fracture and no cleavage. They are soft (2.5-3) and fairly heavy (about 5.5 in specific gravity). The color and streak are very dark lead gray, almost black. The mineral is often tarnished green due to the formation of a malachite, a copper carbonate ($CuCO_3Cu(OH_2)$). Some grains from the Bear Lodge district are tarnished quite blue, due to the formation of covellite (CuS) in minute amounts. When pure, chalcocite contains 79.8% of copper and 20.2% sulphur. Chalcocite does not occur in any abundance anywhere in the Hills as far as known. At the present time no active mining for copper is going on.

16. SPHALERITE (ZnS).

This mineral is also known as blende or zinc-blende. It is quite common in distribution in small amounts throughout the Black Hills, but is not sufficiently concentrated anywhere as far as known to be serviceable as a source of zinc or spelter. It occurs in the vicinity of Galena with the lead-silver ores, near Deadwood on Spruce Gulch, and near Pluma in veins of rhyolite porphyry associated with pyrite (FeS_2), very little chalcopyrite ($CuFeS_2$), calcite ($CaCO_3$) and quartz. In the Tiger Mine near Hayward it is associated with galena, calamine, and smithsonite. In the first three localities the sphalerite occurs in irregular crystalline grains of circular cross section which bear witness to its isometric crystallization, although no forms can be recognized. It is quite black in color and shows excellent cleavage with strong metallic luster on the smooth cleavage face. The luster seems exceedingly bright, almost adamantine, but in other directions than that of cleavage is quite resinous. To this variety which is rich in iron the miners apply the name black jack. This type is readily confused with Galena (PbS), but may be distinguished by difference in cleavage. Thus galena has perfect cubical cleavage, while sphalerite has cleavage parallel to a dodecahedron. Galena is lead gray in color, and is almost twice as heavy as sphalerite. Sphalerite is 3.5-4 in hardness, and about four in specific gravity. The black variety gives us a brownish colored streak. This is the more common variety in the Hills, for example in small amounts near Pluma, also near Spokane, and with some of the lead-silver ores near Pactola, Silver City, Rochford and Galena. It is also known in the Bald Mountain district. Occasionally we get sphalerite associated with limestones in the Black Hills, when it differs decidedly from the above. Its occurrence is, however, rare. Thus it is reported from near Inyan Kara and the Devil's Tower in small grains of a yellowish brown to a reddish brown color and decided resinous luster. To this variety the miners apply the term resin jack. In this case the streak is pale yellow to white and the mineral tends to be free from iron. Resin jack of dark reddish brown color occurs as seams and veinlets in schist in the Tiger Mine near Hayward.

17. CINNABAR(HgS) (?)

This important sulphide of mercury is reported to occur in small amounts on Victoria Creek, and also near Pactola and Rochford (65). No material from the Black Hills is available for description. It is a bright red or vermillion colored mineral with an adamantine to dull or earthly luster. The crystals are usually minute and indistinct. The streak is scarlet. When pure cinnabar is very heavy (8-8.2 in specific gravity). It is soft and brittle. The color, hardness and weight will distinguish it from similar minerals.

18. Covellite (CuS).

This mineral is only known from the Black Hills as a bright indigo blue staining on chalcocite occurring in the Bear Lodge district.

19. GREENOCKITE (CdS).

This mineral occurs very sparingly in minute crystals in the Granite Reef Mine near Custer. It has a brilliant luster, a bright yellow color, and an orange yellow streak. The hardness is 3.5.

20. NICCOLITE (NiAs).

There is considerable uncertainty regarding the occurrences of niccolite within the Black Hills. It is very rare on French Creek. Here it is a pale copper red color, has bright metallic luster, and occurs in disseminated grains in pyrrhotite. Their specific gravity is 7.5 and their hardness 5.5. It is brittle and has a brownish black streak. The last two characteristics serve to distinguish it from native copper. In similar manner niccolite is said to occur on Spring Creek on the Rapid City-Hill City road. The French Creek material in test runs made in the Ivanhoe Mill by Ed. N. Davis is said to have yielded concentrates carrying 7% nickel.

21. PYRRHOTITE (Fe_7S_8) Magnetic pyrites.

This mineral is one of the more common minerals of the Hills, especially so in the mining camps where it is usually associated with gold. Thus it occurs in fair amounts in the Homestake mine and adjacent properties, near Rochford, Mystic, Pactola, Silver City, Custer, Keystone, Sheridan, and in fact in more or less amounts practically anywhere in Pre-Cambrian rocks of the Hills. The luster is metallic, and the color is bronze tinged pale reddish, often inclined towards a peculiar grayish yellow. On exposed surfaces it tarnishes dark rapidly, and often shows iridescence due to the presence of small traces of copper. It differs in color from pyrite and marcasite, which are also very hard, while pyrrhotite is medium in hardness (3.5-4.5). Pyrrhotite is also slightly magnetic, while pyrite and marcasite are never so. The actual composition of pyrrhotite ranges from Fe_5S_6 up to $Fe_{16}S_{17}$, while Fe_7S_8 is more common in occurrence. The following analyses quoted from Sharwood (103 show the composition of pyrrhotite from the Homestake mine:

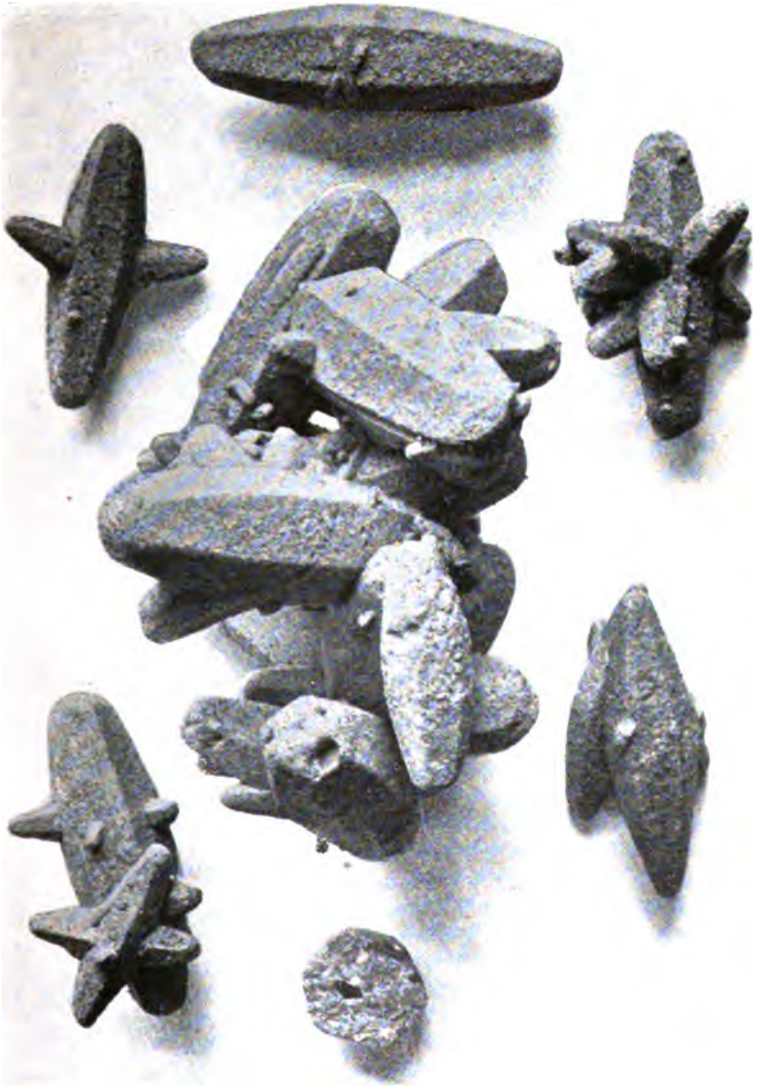

PLATE VIII: Sand-Calcite Crystals from the Miocene of Devils Hill. Foote Mineral Co., Phila.

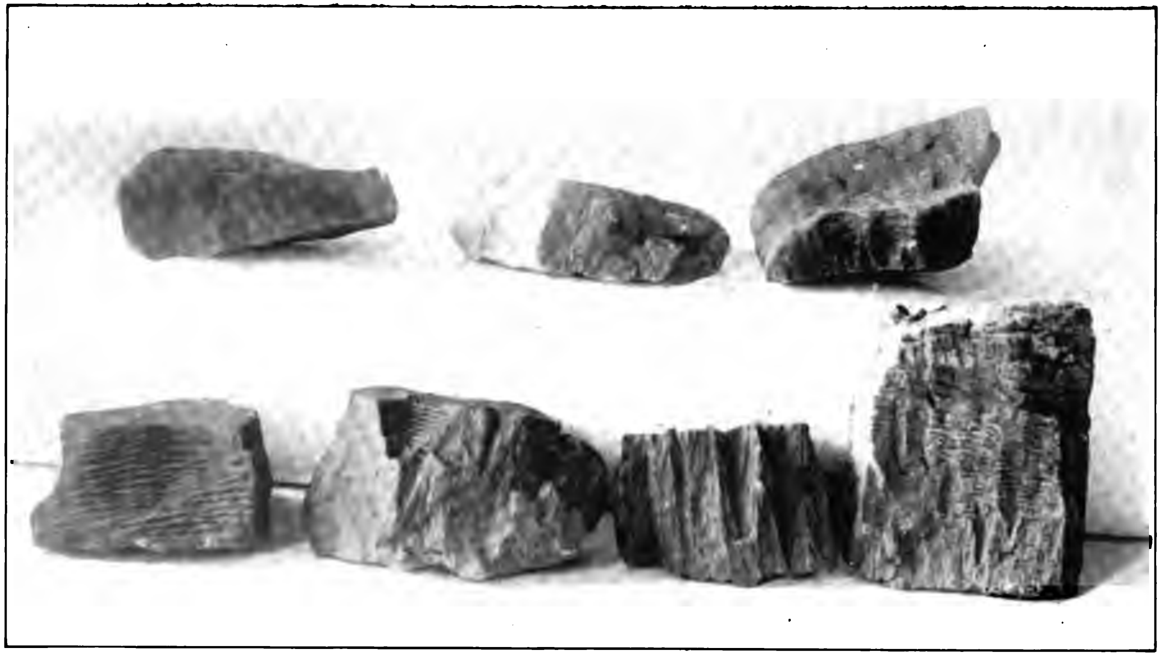

PLATE IX: Various stages of Cone in Cone Structure.
Near the head of the Little Missouri River.

	%	%	%	%	%	%
Insoluble	1.36	3.32	1.8	1.68	6.18	0.88
Iron	59.90	57.6	58.0	59.5	56.14	59.5
Sulphur	39.18	38.59	40.2	37.5	36.92	39.7
Copper	.04	trace	trace	trace	trace	.05
Arsenic	trace	trace	trace	trace	trace	trace
Total	100.48	99.91	100.00	99.68	99.24	100.13
Calculated to pure sulphide—						
Iron	60.45	59.87	59.06	61.35	60.32	60.00
Sulphur	39.55	40.13	40.94	38.65	39.68	40.00

The theoretical percentage composition of Fe_7S_8 is 60.406% iron and 39.594% sulphur, with which the analyses agree quite closely. As a rule the pyrrhotite goes below the average ore in gold value. No definite crystal forms occur as far as known within the Hills. It readily alters to limonite ($2Fe_2O_33H_2O$), which causes a rusty staining on the weathered specimens. Often this change has gone so far that the whole upper portion of a pyrrhotite deposit has completely changed to a rusty cellular quartz or a crumbly limonite. This capping of veins we call gossan.'

22. BORNITE ($Cu3FeS_3$).

This important copper mineral is rare in the Black Hills region. A few scattered localities in the Bear Lodge district afforded some specimens. These are associated with chalcocite and malachite. Bornite has a metallic luster. The color of the above is a pale copper red on fresh fracture, tarnishing rapidly to a purple, green and red iridescence. This gave rise to the miners' terms, "peacock" ore, "variegated" copper ore, or "purple" copper. It occurs granular and as small veinlets and shows no distinct crystal outlines and no cleavage. The streak is grayish black. It is soft (3), and fairly heavy (about 5 in specific gravity). When pure it carries 55.5% copper. The brilliant iridescent tarnish and its softness will serve to distinguish it from chalcocite and from chalcopyrite.

23. CHALCOPYRITE ($CuFeS_2$). Copper pyrites.

This mineral is the most important and most widespread of the copper ores, and occurs in many scattered localities in the Black Hills region, although nowhere in abundance. It is usually associated with pyrite and pyrrhotite in minute amounts; often the only evidence of its presence aside from microscopic examinations, being a green staining on the other sulphides caused by the formation of malachite. In the vicinity of Nemo, Rochford, Sheridan, Pactola, Hill City, and in the Bear Lodge district fair specimens are found. In the last locality chalcopyrite occurs in a decomposed syenitic porphyry associated with tenorite, chrysocolla, and malachite. In the other localities it occurs with iron sulphides in quartz veins, in schists and slates, and also disseminated in pyritous slate. It is a dark brass yellow in color, and often tarnished green due to the formation of malachite ($CuCO_3Cu\ OH_2$). Frequently the exposed surfaces have an iridescent tarnish. The luster is metallic, the streak, greenish black. The hardness is 3.5-4 and the specific gravity varies from 4.1-4.3. It is brittle and breaks with an uneven fracture. When chemically pure it carries 34.5% of copper. No crystals are known from the Black Hills. Its color and hardness serve to distinguish it from pyrite, marcasite, and pyrrhotite, with which it is often confused.

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24. PYRITE (FeS_2).

This is one of the most common minerals in nature and may be found practically everywhere in the Black Hills in more or less abundance. Large deposits occur near Deadwood and Mystic. The gold occurring in quartz veins is usually associated with pyrite and carried by it as small inclusions of native gold. This pyrite has very frequently been decomposed by weathering to limonite ($2Fe_2O_3 3H_2O$), causing the rusty staining and the cellular appearance of many quartz veins. As the mines descend on these veins the sulphides begin to appear in the lower and less altered portions. Pyrite is a light brass yellow mineral with decided metallic luster, and a greenish black streak. It is very hard (6-6.5), cutting glass readily, and medium in weight, the specific gravity varying from 5-5.1. Cubes are the most common crystal forms. These are often well defined and show pronounced striations on the cube faces, with the direction of the striæ mutually perpendicular at the point of contact. Such cubes are fairly common enclosed in quartz in the Algonkian rocks around Deadwood and also in the

Central Hills. Near Deadwood and Pluma pyrite is associated with sphalerite, as for example on Spruce Gulch. The pyrite crystals are very small, but bright and sharp, and in addition to the cube, the octahedron and the pentagonal dodecahedron or pyritohedron can be recognized, usually in combinations. Penetration twins of cubes are common. Frequently we get multiple intergrowths of cubes. One such, from calcareous shale on the eastern border of the Hills, shows an intergrowth of many cubes modified by both the octahedron and the dodecahedron. As has been mentioned before, this mineral decomposes readily when exposed to weathering action and is oxidized into limonite. This change very frequently takes place without the destruction of the original crystal form of the pyrite so that we obtain apparent isometric crystals of limonite. These "pseudomorphs" are described later in the discussion of limonite. The slates of the Central Hills around Mystic, Pactola, Rochford, Silver City, etc., carry disseminated pyrite. This frequently oxidizes to ferrous sulphate ($FeSO_4$) and thus liberates SO_2. This chemical change leads in graphitic portions of the slate to the formation of sulphur, under less powerful reducing conditions the liberated sulphuric acid attacks the slates leaching out soluble constituents. The solutions so formed, trickling into caverns, mine openings or railroad cuts and railroad tunnels are evaporated and deposit melanterite ($FeSO_4 7H_2O$) in delicate pale green crusts associated with white pulverulent Kalinite or Alum ($K_2Al_2(SO_4)_4 24H_2O$) and frequently halotrichite ($Fe_2Al_2(SO_4)_4 24H_2O$). Other sulphates are also present. These sulphates are all quite soluble and have a strong astringent and nauseating taste, hence are quite obnoxious in the springs and small pools located within such shale or slate areas.

Sharwood (103) cites an analysis of pyrite from the Homestake mine, which is as follows:

Insoluble	2.56%	Calculated to pure sulphide.
Iron	46.31%	47.47%
Sulphur	51.26%	52.53%
Copper	.07%	
Arsenic	trace	
Gold	trace	

The theoretical percentage composition of FeS_2 is 46.58% iron, 53.42% sulphur. The variation in composition is probably due to the presence of minute amounts of admixed pyrrhotite. Pyrite is a common accessory in most igneous rocks and is usually formed under conditions of high temperature and pressure. In the eastern United States, as for example in New York, pyrite is mined to some extent and used in the manufacture of sulphuric acid. The value per ton is, however, low and the demand is limited.

25. MARCASITE (FeS_2).

Iron sulphide is also found in the orthorhombic system, when it is named marcasite. Since iron sulphide occurs in the two systems we speak of it as dimorphous (two-form). In distinction from pyrite, marcasite is formed under low pressures and temperatures. Thus the common iron sulphide deposited in the upper part of the earth's crust, which is subjected to the weathering agencies, is usually orthorhombic and hence marcasite. This is the same in hardness as pyrite (6-6.5), slightly paler yellow in color, and slightly lighter in specific gravity (4.9). It is somewhat common in the weathered portions of slates in the Hills. As small veinlets, and as the nuclei and layers in concretions, it occurs frequently in the so-called Pierre Shale along the Cheyenne River. Occasionally in a vug we get a suggestion of crystal form usually flat and tabular, with indistinct faces. Well defined crystals are so far not known from the Hills. Marcasite is frequently associated with gypsum along the Cheyenne and Missouri rivers. In coals and lignites it is commonly present in thin filaments filling cracks. Often it occurs in beautiful small rosettes made up of radiating fibrous crystals, which show practically perfect circular cross sections. It is an injurious ingredient in coal because it yields sulphur on heating which attacks the iron in the grates and linings of the stone. It decomposes readily yielding the same products as pyrite.

26-27. LOELLINGITE ($FeAs_2$). LEUCOPYRITE (Fe_4As_4).

These minerals grade into each other and hence may be considered together. In the Black Hills they are found in association with the tin and lithium deposits of the Harney Peak district. In the Etta mine they occur as small disseminated grains in scorodite ($FeAsO_4+2H_2O$), which is formed by their alteration, and also massive and with arsenolite (As_2O_3). The grains have a metallic luster, are steel-gray to tin-white in color and have a grayish-black streak. They are about 5.5 in hardness and 7.1 in specific gravity. Tests show them to be free from sulphur, and to be slightly tin bearing. This may be due, however, to admixtures of microscopic grains of cassiterite with which they are associated. It is found near Custer in disseminated masses in the "White Spar" mica mine, but here it contains small amounts of sulphur and hence is a variety transitional to arsenopyrite ($FeAsS$).

28. ARSENOPYRITE ($FeAsS$).

This mineral, also called mispickel, is very common in the Black Hills. It is a tin white to steel gray mineral with metallic luster and dark grayish black streak. It is hard (5.5-6) slightly exceeding the loellingite of the Hills and is lighter in specific gravity varying from 5.8 up to 6.4. It is usually considered to be a combination of FeS_2 and $FeAs_2$ in equal proportions. It varies somewhat in composition and by loss of sulphur grades over into loellingite ($FeAs_2$). Such gradational specimens are mentioned under the latter mineral from the vicinity of Custer. Arsenopyrite is a frequent accessory mineral in the gold deposits and occurs practically everywhere in the Hills. Thus it occurs around Custer, Hill City, Spokane, Keystone, Mystic, Rochford, Deadwood, Lead, etc. It is usually associated with other sulphides, pyrite and pyrrhotite especially. Frequently it occurs with quartz. As a rule the arsenopyrite tends to be richer in gold content than the average ore. Thus arsenopyrite concentrates from the Homestake mine varied from .907 oz. to 1.70 oz. of gold per ton, while the ore from which it was taken rarried from .20 to .40 oz. of gold per ton. (Sharwood 103.) Arsenopyrite from the 800-foot level of the Homestake mine had the following composition:

	% found.	% of Sol. Portion.	Calculated for FeAsS
Insoluble	1.80	....	....
Iron	35.10	35.74	34.32
Sulphur	20.86	21.24	19.67
Copper	none	....	....
Arsenic (by difference)	42.24	43.02	46.01
Gold	.0048	....	....

This arsenopyrite is high in iron and sulphur and low in arsenic which is probably due to the presence of occluded pyrrhotite. This would also account for the somewhat low specific gravity (5.87). The crystals of arsenopyrite are often quite well developed, especially when it occurs in chlorite. Most of the crystals are simple prisms (1, 1, 0) modified by bracchy domes having oscillatory growth which is shown by striations parallel to the edge between the two forms. The striations are often curved in a plane that is parallel to the b axis, especially on crystals made up of the prism (a:b:∞c) (1 1 0), and the bracchy dome (∞a:4b:1c) (0 1 4). Cleavage parallel to the prism faces is fair. The tin white color, black streak, and the hardness will serve to distinguish it from all common minerals with which it may be confused. As a further precaution we can heat the mineral highly, when heavy white fumes of arsenic oxide and sulphur dioxide are given off, after which the residue becomes magnetic.

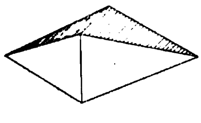

Fig. 43.
Arsenopyrite.

29. SYLVANITE $(AuAg)Te_2$.

Gold tellurides were first recognized in the Black Hills in the siliceous or refactory ores occurring in the Deadwood formation, above the so-called cement ores. Pearce* and later Smith** called attention to the occurrence of tellurium with gold in these ores and carefully worked out the relationship of these elements to each other, coming to the conclusion that they exist in combination as a gold telluride.

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*Pearce, Richard. Proc. Colo. Sci. Soc. vol. V. pp. 144-147, 1895.

**Smith, Frank C. The Occurrence and Behavior of Tellurium in Gold Ores, etc. Trans. Am. Inst. Min. Eng., vol. XXVI. p. 485, 1896.

Subsequently tellurium was also found in ores in the carboniferous limestones on Ragged Top, Dacy Flat, and between Ragged Top and Spearfish Canyon. The gold ores of both of these geological horizons were for a long time a puzzle to the miners, for in spite of good assay values in gold and silver, no native gold was apparent after panning, nor was the per cent of recovery such as to satisfy expectation. Indeed, due to the difficulties inherent to their treatment the term "refractory" became attached to these ores. The first attempt to mine them was made in the Empire mine near Portland (65). The ore averaged $35 per ton, but the recovery by amalgamation was practically nothing and mining was discontinued. Various different methods of extracting values were tried, but none met with much success until chlorination and cyanidation methods were initiated which have since proved effective. The ores in the Deadwood formation occur in two levels, one slightly above the basal conglomerate (which carries free gold) known as the lower contact zone, the other, occurring a few feet below the massive sandstone forming the upper part of this formation, known as the "upper contact" ore. Valuable deposits have also been found in intermediate zones. The ratio of gold to silver is greater in the ores in the lower horizon. The igneous rocks occurring with these deposits, as sills and laccoliths, are often sufficiently enriched in gold and silver to be valuable as ores. As has been shown by Carpenter (14), Smith (45), and especially so by Irving (51) the ores are associated with igneous rocks such as phonolites, rhyolites, etc., and are due to the replacement of sandy dolomitic limestones, by solutions which ascended by means of fractures called "verticals." These ore-bearing solutions also enriched some layers of the underlying quartzites and in some cases formed ore deposits in the carboniferous limestones above. The minerals in the unaltered ore are quartz, arsenopyrite, pyrite, barite, stibnite, gypsum, wolframite, fluorite, uranocircite, tetradymite, and apatite. The occurrence of the last five minerals is evidence that the solutions had their origin in the igneous rocks which are associated with the ore wherever it occurs. Practical miners usually distinguish between two types of ore, the blue siliceous, and the oxidized ore or red or brown ore. The blue ore is a more or less banded, highly siliceous dolomite. This in many cases has been almost entirely replaced by quartz and Irving (101 also 73) mentions the occurrence of quartz pseudomorphs after dolomite occurring in beautifully defined rhombohedra. The ore is very hard, dense and tough. Glauconite, a green hydrous silicate of iron and potassium, is present and gives a somewhat greenish cast to some ore which is usually, however, a dark slate blue. When exposed to weathering the iron minerals present are quickly oxidized into hematite (Fe_2O_3) and limonite ($2Fe_2O_33H_2O$), which stain the ore brown or red. Weathering also decreases the hardness of the ore, rendering it at times almost as friable as clay. In the unaltered blue ore, gold telluride has been reported as an occasional silvery flake (73). It is very finely disseminated, however, and hence usually not apparent. In the oxidized portions the gold occurs native, and the tellurium probably as an oxide. Deveraux (3) mentions the occurrence of native gold in a sponge-like brown colored form, which is the usual type of gold derived from oxidized telluride. The following table gives a series of analyses of both the blue and the oxidized ores and shows the proportion of gold, silver and tellurium in ounces per ton:

ANALYSES OF REFRACTORY SILICEOUS ORES.

		Gold.	Silver.	Tellurium.	(Content oz. per ton).
1.	Red Ore	.574	2.875	8.426	Smith, F. C., 42.
2.	Blue Ore	.325	1.055	4.03	Smith, F. C.. 42.
3.	Red Ore	.72	58.52	16.7	Smith, F. C., 42, Russell.
4.	Red Ore	1.928	11.172	26.69	Smith, F. C., 42, Welcome.
5.	Blue Ore	4.36	16.01	12.95	Smith, F. C., 42, Welcome.
6.	Blue Ore	.86	5.75	6.17	Smith, F. C., 42, Welcome.
7.	Red Ore	1.22	.87	5.78	Smith, F. C.. 42, Double Standard.
8.	Red Ore	4.61	5.52	22.04	Smith, F. C.. 42. McPherson.
9.	Red Ore	3.42	3.43	21.58	Smith, F. C., 42, Golden Reward.
10.	Red Ore	3.44	3.36	34.56	Smith, F. C., 42, Tornado.
11.	Blue Ore	.44	255.08	10.24	Smith, F. C.. 42. Rose Hannibal.
12.	Red Ore	5.20	4.8	56.20	Smith, F. C., 42.
13.	Fresh Ore	17.34	1.21	29.26	Smith, F. C., 45, Dacy.
14.	Blue Ore	2.95	4.75	----	Irving, J. D.. 73.
15.	Red Ore	.42	.62	----	Irving, J. D., 73.
16.	Fresh Ore	15.25	4.75	----	Irving. J. D., 73, Carbonif. l. s.
17.	Fresh Ore	.06%	.02%	.03%	Same analysis as above.
18.	Clay Ore	2.47	.9	----	Irving, J. D., 73. Tornado.

The average of nine analyses lead F. C. Smith (46) to the conclusion that the gold, silver and tellurium are present in the form of sylvanite (AuAg) Te_2. The average composition, provided all the gold, silver and tellurium are in one compound, would be for the nine analyses he quotes:

Tellurium	59.97
Gold	7.64
Silver	32.39

An ore from the Dacy mine gave the following ratio:

Tellurium	61.20
Gold	36.27
Silver	2.53

Smith (46) believes that the gold and silver present in the carboniferous ores is also sylvanite. There are, however, other tellurides present in these ores aside from the gold and silver compounds. Thus tetradymite (Bi_2Te_3) free from sulphur, occur in these ores and has been identified by the writer from the vicinity of Pluma and also from Terry. (Sharwood (103) also mentions a bismuth telluride from the Homestake, it may be of interest to note). Altaite (PbTe), the lead telluride, also occurs in these ores which will necessitate further revision in the apportionment of tellurium to gold and silver. Thus it is hardly safe to attribute all to gold and silver. No analyses, at present available, make any mention of bismuth. Lead has been determined in several cases, but due to the presence of galena (PbS) its percentage alone is of no diagnostic value from this standpoint. It is also probable that most of the tellurium analyses are not absolutely reliable due to the minute percentages present. Analyses made by Messrs. Curran and O'Brien in connection with their thesis work in the State School of Mines showed from a trace up to 6.4 oz. of tellurium per ton, lower values as a rule than those cited in the table. In the present state of knowledge concerning these ores it is hardly safe to make any claim as to the identity of the particular gold and silver telluride, if any present. If we confine ourselves to the ratios of gold and silver, we are impressed by the great differences in their ratios in the series of analyses and are confronted with the possibility that the compound runs the whole gamut of changes from a practically pure gold telluride to a straight silver telluride.

The common gold silver tellurides and their compositions are as follows:

	Ratio of Silver to Gold
Hessite Ag_2Te	587.9-1 to 3.09-1
Petzite $(AgAu)_2Te$	2.66-1 to 1.66-1
Sylvanite $(AuAg)Te_2$	1-1.90 to 1-2.35
Calaverite $AuTe_2$	1-11.56 to 1-18.12

The ratio of the silver to the gold content are calculated from analyses in Dana's System of Mineralogy, VI. Edition. The ratio of the silver to the gold in the refractory siliceous ores varies from 1-579 to 1-14.3. We are not justified, however, in apportioning all the silver to the gold because the galena present in the ore is argentiferous, and some of the ores show gradations into argentiferous galena deposits. Cerargyrite ($AgCl$) and embolite ($AgClBr$) occur also in these ores. Some silver must be attributed to these latter minerals, but since they are usually decomposition products formed from the silver minerals in the zone of weathering, they may not affect our reasoning. It seems that all speculation or statements regarding the actual mineral carrying the gold and silver should be left until we are able to obtain a pure specimen for analysis and study, or until we have analyzed a rich concentrate for all elements present and are enabled to apportion them intelligently on the basis of known mineral occurrence.

Mr. Zay Jeffries, a graduate of the School of Mines, identified sylvanite from the vicinity of Custer. This occurs in quartz, and in quartz-pyrite veins and is usually associated with tetradymite (Bi_2Te_3), which is highly gold bearing.

The gold tellurides are silver white, often inclined towards steel gray in color. Very rarely they are pale yellow. The streak varies, it may be black, but is usually the same as the color and shiny metallic. They are all very soft and can be scratched by the finger nail. They vary in specific gravity from 7.9 to 9.04. Tellurides may be recognized by the fact that if heated with concentrated sulphuric acid the solution turns a beautiful rose color. If gold silver tellurides are highly heated the tellurium is driven off and the alloy of gold and silver remains. Gold-silver tellurides are readily oxidized when exposed to weathering, forming free gold and tellurium oxide. Hence the upper portions of telluride deposits usually contain free gold, the lower portions the unaltered tellurides. These minerals are so rare and usually occur in such minute quantities that determinations should be left to an experienced chemist or mineralogist.

The siliceous refractory ores containing tellurides are especially important in addition to the localities mentioned, near Lead, Deadwood, Kirk, Portland, Terry, Bald Mountain, Ragged Top, Elk Mountain, Squaw Creek, and Garden.

For a thorough and systematic discussion of these ores the reader is referred to pp. 37-50, Bulletin No. 6, S. D. State School of Mines, "The Mineral Wealth of the Black Hills," by Dr. C. C. O'Harra.

III. SULPHO SALTS.

In this group we include those minerals that are double sulphides of a metal and a semi-metal. Only a few of these are known from the Black Hills.

30.34. THE LEAD-ANTIMONY SULPHIDES.

There occur in the vicinity of Silver City a number of lead antimony sulphides, which are usually spoken of as jamesonite. These occur in milky quartz veins which cut across the schistosity of the slates. They appear to be genetically connected with a zone of rotten slate—probably a fault plane—running in a general north-northeast direction. The lead antimony sulphides are sporadic in occurrence, coming in irregular shoots and pockets. They are associated with pyrite, chalcopyrite and sphalerite, often in fair sized grains. Even carefully picked and apparently pure specimens when polished and examined under the microscope show minute grains of these other sulphides. It is not surprising, therefore, to find traces and even small percentages of copper, iron and zinc in the apparently pure mineral. These should not be referred to the lead antimony sulphides as has been done in some cases (86), but should be eliminated as belonging to impurities.

The lead antimony sulphide minerals are a light gray color, have a metallic luster and a grayish black streak. They vary from two to three in hardness and vary in specific gravity from 5 to 6.5. Very often they occur in crystalline aggregates of many grains showing perfect small cleavage planes which have a very bright luster, and give the mass a felt-like appearance. Occasionally we get compact, somewhat fibrous masses, which suggest a bunch of feathers crowded closely together. Imperfect prismatic radiating aggregates occur. These exhibit a perfect cleavage perpendicular to the elongation and an imperfect cleavage parallel to it. Sometimes these lead antimony sulphides occur in almost hair-like crystals penetrating quartz in all directions. These are easily confused with stibnite (Sb_2S_3), which occurs in the same manner. In the Calaboga mine, north of Merritt, the so-called jamesonite occurs in a peculiar, very dense and massive form, which has a hackly fracture almost like steel.

The following table shows analyses of jamesonite and other lead antimony sulphides and ores from the Black Hills.

	I.	II.	III.	IV.	V.	VI.
Insoluble	1.13	.49	...	...	...	...
Silica	...	...	...	...	...	...
Ferrous oxide	...	...	6.02	3.85	...	...
Iron	1.30	trace	...	...	...	...
Lead	51.15	62.85	7.95	32.00	21.17	13.85
Antimony	26.99	18.20	4.20	17.50	9.25	3.02
Sulphur	18.90	17.51	4.10	9.00	...	...
Copper	.24	.86	...	...	...	...
Zinc	.05	...	1.50	...	...	...
Cobalt	trace	...	...	...	...	...
Lime	...	...	.70	...	...	...
Al_2O_3	...	...	5.33	1.30	...	...
Arsenic	...	trace	.30	...	...	...

I, Headden (86); II, Headden (86), also tr. cadmium, bismuth; III, and IV, Ives and Ossa, Thesis, S. D. School of Mines, 1908; V and VI, M. F. Coolbaugh (not tested·for other elements).

Allowing in every case for the impurities present and taking the remainder of the sulphur and combining it with the lead and antimony, we get the following percentage composition (in numbers V and VI allow enough sulphur to form PbS and Sb_2S_3 respectively):

	I.	II.	III.	IV.	V.	VI.
Lead	53.60	64.00*	52.80	54.70	56.80	68.40
Antimony ...	28.20	18.60	27.70	29.91	24.80	14.90
Sulphur	18.20	17.40	14.50	15.39	18.40	16.70

Working out the ratios of PbS and Sb_2S_3, we get the following:

I.	II.	III.
260 PbS	309 PbS	255 PbS
103 Sb_2S_3	78 Sb_2S_3	115 Sb_2S_3
Excess 29Sb		Excess 9 S

IV.	V.	VI.
265 PbS	275 PbS	331 PbS
73 Sb_2S_3	103 Sb_2S_3	62 Sb_2S_3
Excess 103 Sb	Deficiency 8S	Excess 5 S

If we take this into consideration the ratio of PbS to Sb_2S_3 becomes practically 265 PbS.124.5 Sb_2S_3. A series of analyses on carefully picked undecomposed and apparently homogeneous minerals gave Mr. George Stowell the following percentages of lead, VII, 82.40; VIII, 66.25; IX, 44.68; X, 36.06; XI, 34.74; XII, 33.62, and XIII, 28.31%. The specific gravity of the specimens varied from 6.5 to 5.0.

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*Slight amounts of copper replace the lead (85). In analysis IV, we have quite an excess of Sb. This is due to the fact that the ore was decomposed and that alteration products, such as bindheimite and cervantite, are present, which result in a loss of sulphur. These resulting oxides seen, however, less soluble in water than the primary sulphides, as they are not removed nor concentrated secondarily.**

**Comey, "Dictionary of Chemical Solubilities." Lead Antimonate is insoluble in water, incompletely decomposed by acids. Antimony oxide, insoluble in water, attacked, but slightly by hydrochloric acid. Insoluble in nitric acid (Prof. M. .F. Coolbaugh). Antimony sulphide is readily soluble in cold nitric acid.

Our knowledge of the lead antimony sulphide minerals is well summarized by Hintze*, who recognizes the following minerals:

	Pb.	Sb.	S.
Zinkenite—PbS Sb_2S_3	35.99	41.71	22.30
Plagionite—5PbS $4Sb_2S_3$	40.75	37.78	21.47
Warrenite—3PbS $2Sb_2S_3$	44.69	34.53	20.78
Heteromorphite—7PbS $4Sb_2S_3$	48.01	31.80	20.19
Jamesonite—2PbS Sb_2S_3	50.84	29.46	19.70
Semseyite**—9PbS $4Sb_2S_3$	53.29	27.45	19.26
Boulangerite***—5PbS $2Sb_2S_3$	55.42	25.69	18.89
Meneghinite—4PbS Sb_2S_3	64.07	18.56	17.37
Geocronite—5PbS Sb_2S_3	67.58	15.67	16.75
(Kilbrickenite—6PbS Sb_2S_3)	70.10	13.60	16.30

The last named mineral is recognized as a distinct species by Dana, but not by Hintze, who refers it to geocronite. In addition to the above, we might also mention the two extreme end products, namely, galenite (PbS) and Stibnite (Sb_2S_3). Galenite frequently carries Sb as an impurity, probably in solution as Sb_2S_3. Thus Hintze**** mentions a series of galenite analyses of specimens from Bottino in which the antimony content varies from 3.31 up to 9.69%, and mentions one galena from Pilar, Illimani which carries 15.38% antimony. Out of 34 analyses of galena quoted, 16 show appreciable amounts of antimony, and excluding the one extreme value of 15.38%, average 2.91%. Stibnite (Sb_2S_3) is more apt to be free from lead, the highest lead content being 2.25% in a stibnite from Magurka*****. Others show from .23 to 1.84% of lead. Thus we are confronted with the fact that we have a complete gradation from the zinkenite ($PbS.Sb_2S_3$) up into the pure galenite. (PbS). Minerals representing every intermediate stage between the two in composition can be found. The gradation from zinkenite ($PbS.Sb_2S_3$) into pure stibnite (Sb_2S_3) is not as complete. No analyses are cited which show from 3 to about 30% of lead. From the above data it would almost appear that lead and antimony sulphides are capable of crystallizing out from solutions in almost any proportion above the ratio PbS :Sb_2S_3=1 :1. Any table of analyses will bear out this conclusion and the divergencies of the different analyses of any one mineral will show gradations to the minerals above and below it in the list given. When the ration PbS to Sb_2S_3 is less than one, it would appear, on the face of the data available, that Sb_2S_3 is crystallized alone until a ratio above 1 :1 is reached, when a lead-antimony sulphide can begin to form.

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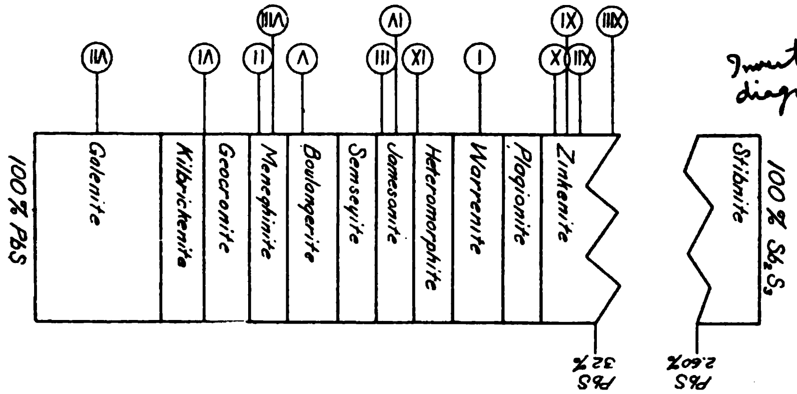
*Hintze's Handbuch der Mineralogie.

*Dana gives 7PbS $3Sb_2S_3$.

***Dana gives 3PbS Sb_2S_3.

****Hintze, Handbuch der Mineralogie, pp. 512-513.

*****Hintze, op. cit. p. 392.



Insert diagram

Diagram showing composition of various Lead-Antimony sulphides and showing the positions of the different Black Hills specimens according to analyses.

Diagram showing composition of various lead-antimony sulphides and showing the positions of the different Black Hills specimens according to Analyses.

The diagram graphically shows the relationship in composition of the different lead antimony sulphides to each other and also shows the relative position of the Black Hills specimens whose analyses are quoted above.

The variable analyses of these specimens seem to show that we either have a series of mixed crystals or mixtures of various minerals. Polished sections of such minerals are shown on plate III. The upper right hand photograph as well as the lower left hand one seem to show homogeneous substances. They represent the specimens of analyses VIII and XIII respectively, which show 66.25 and 28.32% of lead. The other specimens show lead percentages as follows, upper left 34.74%, center 44.68%, lower right 33.62%. As is readily apparent they show a coarser crystallinity than the above minerals. It may be of interest to note that the upper right hand specimen appears dense and homogeneous to the naked eye, while the lower left hand specimen shows coarse crystalline structure.

The apparent homogeneity of the Black Hills specimens, their divergent chemical composition, their similar physical characteristics would seem to indicate that they represent a series of mixed crystals either of Sb_2S_3 and PbS, or of some intermediate sulphantimonide of lead with another, or either of these end products. Judging from chemical analyses and specific gravity determinations alone, the following minerals are indicated, jamesonite, meneghenite, boulangerite, semseyite, and geocronite. Probably also zinkenite and warrenite. To the author the first explanation seems the more probable, although much further study is necessary to clear up this problem.

35. PYRARGYRITE Ag_3SbS_3.

This sulph-antimonide of silver occurs in minute amounts in disseminated grains and thin films in some of the lead-silver deposits in the Northern Hills. It is dull to metallic in luster, and is nearly black in color, inclining towards reddish. If a thin flake is held up to strong light it appears deep red. The streak is a reddish purple. In hardness it is 2.5, hence very soft. Chemical tests are necessary for its determination. It is associated with galena (PbS), sphalerite (ZnS), cerussite ($PbCO_3$), argenite (Ag_2S), and cerargyrite (AgCl) near Galena and Spokane.

36. TETRAHEDRITE $Cu_8Sb_2S_7$.

This is a fine grained mineral varying from a light to a dark lead gray in color and having a decided metallic luster. It is soft, varying from 3 to 4.5 in hardness. The specific gravity is practically 5, hence it seems heavy. The streak is brownish black. The common crystals are tetrahedrons, which give the name for the mineral, but so far no crystals are known from the Black Hills only irregular disseminated masses stained with the copper carbonates (azurite and malachite). These occur in the vicinity of Deadwood between Whitewood and Yellow Creek, and were

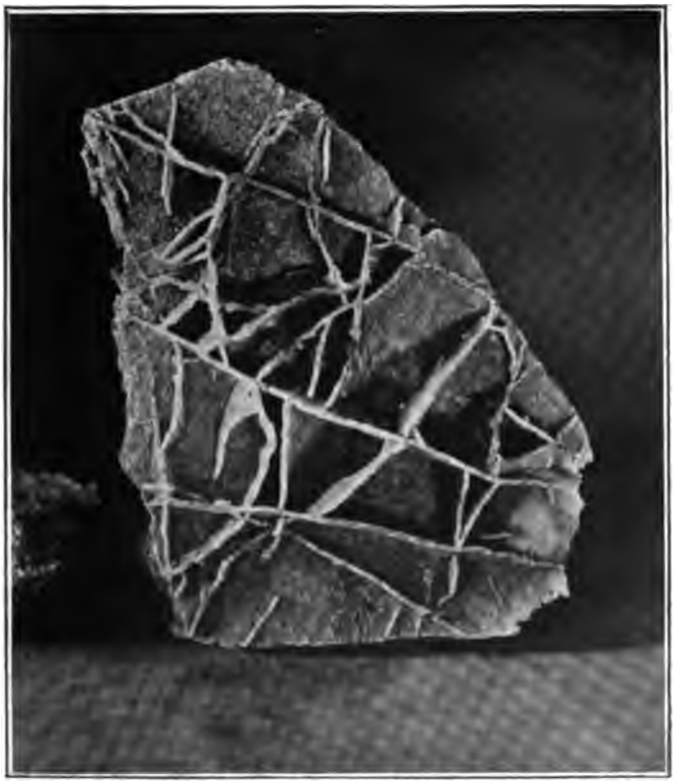


PLATE X: Boxwork.
Calcite and Aragonite,
Wind Cave.
(⅓ natural size.)

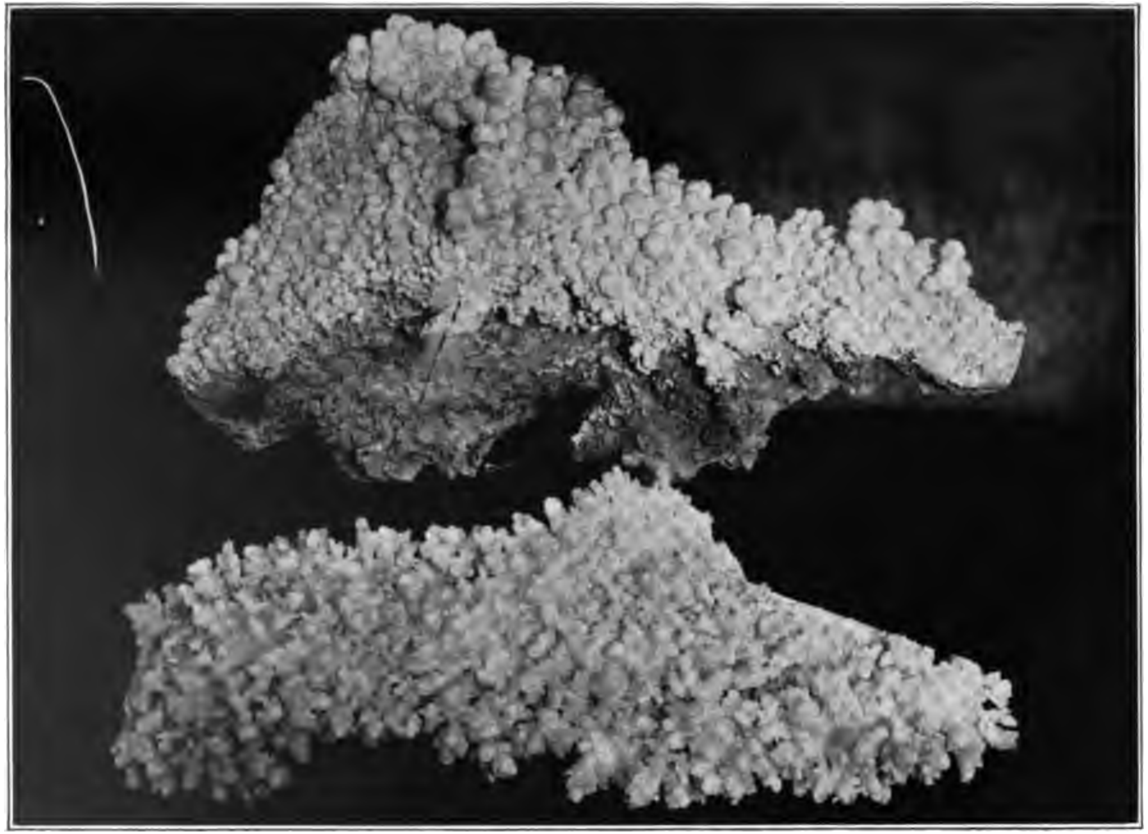


PLATE XI: Popcorn Aragonite, Wind Cave.
(½ natural size.)

first mentioned by Irving (74, p. 95). This is the only occurrence of tetrahedrite so far known within the Black Hills region.

37. STANNITE Cu_2FeSnS_4.

This mineral is also frequently called tin pyrites. It is rare in nature, but in certain districts, as for example in the Zinnwald in Germany, and in Cornwall, England it was for a long time quite important as an ore of tin. It has been described from the Black Hills by W. P. Headden (32), but is apparently rare, as only several specimens appear to have been collected. The following description is condensed from Headden's.

On fresh surfaces the luster is metallic and the color grayish black. It tarnishes blue and bronze. The hardness is 4, and the specific gravity is 4.534. The streak is black. The specimen studied was in an advanced state of alteration and was enveloped by an earthy mass, dirty green to brownish yellow in color, which towards the interior was copper green to greenish black in color. This alteration product is cupro-cassiterite. An analysis of the stannite gave the following result:

Sulphur	28.26
Tin	24.08
Copper	29.81
Iron	7.45
Zinc	8.71
Cadmium	.33
Antimony	trace
Insoluble	1.51

The stannite came from the Peerless mine, near Keystone.

The writer was fortunate in securing several fine specimens of stannite which were found by Mr. A. M. Lane in the Etta mine. The Stannite occurs in irregular small masses in milky quartz on the outside of a huge spodumene log. It has a fine bluish-black color and a black streak. It is not quite 4 in hardness, hence readily scratched by a knife. The specific gravity is 4.63. This is also a trifle too low, due to the presence of some admixed cupro cassiterite, to which the stannite seems to decompose.

IV. HALOIDS.

Under this heading we include those minerals that are compounds of a metal and some halogen element, such as chlorine, bromine, iodine, or fluorine.

38. HALITE NaCl.

This mineral also called rock salt, furnishes practically all the salt of commerce. Within the Black Hills region it is not present in any large amounts and as halite is exceedingly soluble in water it is leached out rapidly and carried away by the ground water. Its presence is attested by a vigorous spring of salt water near Newcastle, Wyo., and by pseudomorphs after halite found in sandstones near Piedmont.

39. CERARGYRITE AgCl.

This silver chloride has been frequently met with in various mining camps of the Hills. It is usually restricted to the upper workings of the mines where it has been formed by the alteration and decomposition of argentiferous galena and possibly argentite (Ag_2S). Here it is usually associated with ocherous iron oxide, cerussite ($PbCO_3$), anglesite ($PbSO_4$) the phosphate of lead, pyromorphite, other secondary minerals, and unaltered grains and masses of galena.

In color it varies, near Carbonate it occurs pearl gray in color, inclining towards greenish, in the Trojan mine, near Portland it is greenish in color, in the Galena district, pearly gray. It occurs in masses and grains disseminated through the ores, also as thin veinlets filling minute fractures and occasionally as a thin film coating quartz crystals in vugs and seams (74). On exposure to light, cerargyrite quickly loses its color and becomes a violet brown, which is sometimes almost black. The luster varies from dull to characteristic waxy, with the latter the more common. It is very soft and readily scratched by the finger nail. To the knife it offers a resistance somewhat like wax or horn, hence the miners apply the name horn-silver to this mineral. No crystals have been observed. It occurs near Galena, Carbonate, Spokane, Portland and Silver City.

40. EMBOLITE Ag (BrCl).

In association with the cerargyrite, as for example in the Trojan mine, some of this silver chloro-bromide occurs. It has practically the same characteristics, but is more greenish in color and gives a chemical test for bromine. No specimens are known from elsewhere in the Black Hills.

41. FLUORITE CaF_2.

Occurs generally associated with the siliceous refractory gold ores of the Black Hills and has been mentioned in the discussion under gold tellurides. Usually it is so finely disseminated through the siliceous ores as to impart to them a decidedly violet or purple color. The individual grains are in this case so small that they can not be recognized by the unaided eye. It occurs in this way in the vicinity of Portland, Terry, on Bald Mountain, Lead, Deadwood, etc. Occasionally we get the crystals of fluorite beautifully developed as small cubes lining cavities in the ore. Such vugs occur frequently in the Bald Mountain area. The cubes of fluorite, usually very small, are at times white and transparent, but more often a delicate green, and most frequently deep purple in color. They possess perfect cleavage (octahedral). They are 4 in hardness, and 3.2 in specific gravity. The luster is vitreous and often quite bright. The streak is colorless. About two miles north of Lead there are several small veins of coarsely crystallized fluorite associated with celestite ($SrSO_4$). The masses are practically pure white, but in places tinted quite purple. They show the octahedral cleavage especially well developed. In addition to the localities mentioned, it also occurs in the Bear Lodge district, and near Black Butte.

From the pegmatites of the Hugo Mine near Keystone, the writer obtained through the kindness of Mr. Ed. N. Davis, several specimens of fibrous to columnar apatite, with which is associated a little fluorite. This is interstitial between the apatite and is usually in grains ¼ inch or less across. These are colorless and transparent, or occasionally tinted a very pale purple. The grains show excellent cleavage, and minute tetrahedra can readily be obtained by a blow of the hammer, proving that the cleavage is octahedral.

Fluorite had not been known before from the pegmatites of the Southern Hills. Its occurrence, even as a rare constituent, is of scientific interest, because, although elsewhere it is a common accessory mineral in tin ores, it was thought to be absent in the Black Hills tin deposits.

Fluorite also occurs in small amounts associated with gold and bismuth telluride veins in the Southern Hills. Such occurs near Hayward and on Frank Todd's claims near Custer.

42. ATACAMITE $CuCl_2 3Cu(OH)_2$.

This oxychloride of copper has been found in small amounts in the weathered portions of the lead silver deposits near Carbonate. Here it is found with cerargyrite ($AgCl$), matlockite (Pb_2OCl_2), and other secondary minerals such as cerrusite ($PbCO_3$), pyromorphite ($3Pb_3P_2O_8+$ $PbCl$(etc. It occurs as a green staining and as fibers of a bright to a dark green color, with apple green streak. It is readily confused with malachite ($CuCO_3Cu(OH)_2$) and with chrysocolla ($CuSiO_3 2H_2O$) staining. In these cases a chemical test is necessary to distinguish them. Thus dissolve them in nitric acid (HNO_3) and add a slight amount of silver nitrate ($AgNO_3$) when atacamite will yield a flocculent white precipitate of silver chloride which quickly tarnishes a violet brown. The other two minerals will give no result. It also occurs in small amounts in the Trojan mine near Portland (74).

43. MATLOCKITE Pb_2OCl_2.

This oxychloride of lead has been identified by Fowler (74 p. 178) occurring with the same association as atacamite. No specimens are available for description.

Usually it occurs in tetragonal crystals that are tabular, have adamantine to pearly luster, a yellowish color, and a colorless streak. It is soft (2.5-3) and very heavy (specific gravity 7.21). It is a very rare mineral.

44. FLUOCERITE ($R_2 O F_4$) (R=Cerium metals)

This mineral is reported by Dr. Herman Reinbold (Personal communication) as occurring in delicate green minute crystals in the refractory siliceous gold ores of Bald Mountain in the Northern Hills.

V. OXIDES.

This is one of the important groups of minerals within which we include all compounds of a metal or semi-metal with oxygen. Some of these contain water, some do not, hence we subdivide the group into anhydrous and hydrous oxides.

45. QUARTZ SiO_2.

Quartz is one of the most common minerals exceeding far in abundance any other, with the exception of feldspar. Silicon (Si) is next to oxygen the most abundant element. It is always held in combination with oxygen either as a simple oxide, such as quartz, or as a silicate i. e., a compound of silica (SiO_2) and some oxide, as for example orthoclase which is $K_2O\ Al_2O_36SiO_2$, a potassium aluminum silicate.

Quartz when pure is colorless and transparent, has a vitreous luster and a colorless streak. It is 2.65 in specific gravity, and 7 in the scale of hardness, hence is harder than steel, and cuts glass readily. It has no cleavage, but finely developed conchoidal fracture. In crystallization it belongs to the hexagonal system. As a rule the crystals are hexagonal prisms and appear to be terminated by a hexagonal pyramid. This is, however, made up of two rhombohedrons combined in such a way that their crystal axes coincide and the rhombohedron face of one cuts off the edges of the other. That this relationship is true is shown by the lack of hexagonal symmetry in the etch figures, in the behavior of light when the mineral is examined under the petrographic microscope, and by other physical properties. Such apparent hexagonal prisms modified by two rhombohedra occur usually in small, often minute, clear and colorless crystals in vugs in quartzites and with the gold ores near Terry, Portland, Bald Mountain, Deadwood, Bear Lodge and elsewhere. This crystal type also occurs in pro-

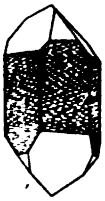


Fig. 44.
Typical Quartz Crystal.

fusion in beautiful geodes and veins in the South Dakota Bad Lands. Dr. O'Harra (100) states that the finest are found near Imlay. These are usually small. Larger ones come from near the mouth of Medicine Root Creek. In size the crystals vary up to one-half inch in diameter. Some of the quarts crystals are white, and when they are fine, resemble sugar, hence they were called sugar geodes. The rhombohedra are usually unequally developed so that one set of alternate faces is small and the other set larger. The prism faces are usually marked by fine striations in a plane perpendicular to the long (C) axis. In some of the igneous rocks of the Northern Hills such as the porphyries we get beautiful little crystals of quartz, usually colorless, which are apparently made up of a simple hexagonal bipyramid. These weather out of the rock and can be found in the soil and gravel near them. Scott (44) mentions the occurrence of crystallized quartz on Box Elder and Jim Creeks.

Quartz occurs in a great number of varieties within the border of the Black Hills. These may be divided into two classes (a) phenocrystalline that is, those in which the component grains or crystals are visible and which have a vitreous luster, and (b) cryptocrystalline, those which are massive and dense, and the component crystals of which are microscopic.

(a) Phenocrystalline Varieties.

1. Rock crystal, the ordinary colorless and clear variety. The crystals above described fall in this group. These are transparent and are common in many veins. Ordinary sand is to a large extent made up of rounded grains of quartz and usually rock crystal. This variety may be found practically anywhere.

2. Amethyst, is a transparent translucent variety of a purple to a bluish violet color. It is reported by Mr.

Scott* on Warrens Gulch, Box Elder Creek, and Bear Butte Creek. The color is supposedly due to the presence of manganese oxide.

3. Milky Quartz. As the name indicates this is a milky white variety. This is very characteristic of mineral veins, and is the quartz met in the gold quartz veins practically everywhere where they are found. It is also the variety of quartz most common in the lead-silver and the lead-antimony deposits near Spokane, Carbonate, Galena, Rochford, Silver City, etc. The milky color appears to be due to the presence of innumerable minute cavities filled with gases. These cause multiple reflection of light in the same manner as foam on water, and hence appear white. A striking and unusual variety, bluish white in color and slightly milky, with a somewhat opalescent luster occurs in the Harney Peak district.

4. Greasy Quartz. Near Custer in some of the pegmatites and quartz veins we get a somewhat cloudy quartz of greasy luster. This is so pronounced and strongly exhibited that it is difficult to believe it only on optical effect.

5. Rose Quartz. The Black Hills affords some of the most beautiful rose colored quartz known. Most of this occurs in the vicinity of Custer, and other localities around Harney Peak. The color very often is a beautiful and deep rose, and since the mineral takes a very high polish due to its density and hardness, it makes striking and pleasing ornaments. Much of the rose quartz is penetrated by irregular fracture cracks along which iron bearing solutions have circulated and caused a rusty coloration. Small pieces can be broken out of the mass which are entirely free of these stains. If the color is very pure and the specimen is clear, it can be used as an ornamental stone in jewelry. Most of the rose quartz produced in the United States comes from the Black Hills, the ônly other producer being California. The total amount produced, however, is not very large and fluctuates greatly from year to year. The color in rose

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*Private communication.

quartz is supposedly due to the presence of titanium oxide or manganese oxide. Dana states that it may fade on exposure to light. Dr. O'Harra informs me that specimens in the School of Mines collection for the last 10 or 12 years, constantly exposed to light, have maintained their color perfectly. Another especially deep colored specimen was found by Dr. O'Harra in Pleistocene stream gravels near Hayward. When found it was exposed to the light. It had been transported several miles, but in spite of this had maintained its deep rose color.

6. Smoky Quartz. Due to minute inclusions of organic compounds, quartz very frequently is a smoky yellow or brown and even black in color. It occurs thus in pegmatites near Harney Peak, frequently so dark as to be only weakly translucent.

7. Sagenitic Quartz. This is applied to quartz penetrated irregularly by needle-like crystals of other minerals. A variety of amethyst which is penetrated by many brown colored rutile crystals, occurs on Box Elder Creek, near the head of Jim Creek*.

8. Aventurine is a variety of quartz that is spangled golden green or silvery due to the inclusion of many minute flakes of mica or of hematite. If the spangling is perfect it makes a pleasing ornamental stone popularly known as gold stone. Most of the Aventurine and gold stone in the jewelry trade are artificial since they are more striking than the natural. Quartz with spangling of hematite is reported from Box Elder Creek.

(b) Cryptocrystalline Varieties.

9. Chalcedony. This is a variety made up of microscopic crystals densely intergrown. These crystals are orthorhombic and should be considered a distinct mineral. It has a fine bluish white color and the luster of pure wax. It may be quite highly translucent. It is quite common in the Bad Lands occurring as veinlets and also associated with sandstone dikes (100). It is hard and resistant to

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*Private communication by Mr. Scott.

weathering and protrudes above the enclosing clays in jagged ridges. These break off and in many places the whole surface becomes shingled, as it were, by small plates of chalcedony. The veins frequently show a pronounced banding of alternate bluish and less translucent white layers. Often the walls of the vein are covered with chalcedony while the central part is made up of well defined tightly interlocking colorless quartz crystals. Frequently parts of the vein are not entirely closed, but leave cavities whose walls are lined with beautiful sparkling little crystals of quartz. Cavities in these Bad Lands deposits are often lined with chalcedony, which weather out of the rock on account of the hardness and resistance of the silica and yield more or less rounded forms which may be hollow, and are termed geodes. Projecting crystals are frequently broken off on the inside and cause a rattle when the geode is shaken. In this case they are popularly called rattle stones.

10. Agates. This name is applied to varieties made up of definite differently colored layers. The color of quartz as we noted before is determined by some metallic oxide dissolved in it. If thus the character of a solution, which is depositing quartz in a fissure or a cavity changes, we get a change in the coloration in the layers of quartz deposited. Agates may be found in many of the creeks of the Hills and in many areas within the Bad Lands. They are usually chalcedony, and are commonly banded alternately white and gray. Such agates may be colored artificially and as they are capable of taking a high polish they would make fair ornaments. Specimens of agates are found in the gravels of the different streams and also on high gravel terraces. The colors are nearly always dull. Since many occur in large size they would make acceptable ornaments after polishing and coloring.

11. Chert is an opaque gray colored dense variety, with a somewhat splintery fracture. The name is usually applied to impure rocks very rich in flint. Such occur as nodules in many limestones. Banded cherts made up of

red and gray layers occur in the vicinity of Deadwood. These are capable of taking a high polish and make handsome ornaments. These occur in carboniferous limestones and in gravels in their vicinity. Chert concretions are especially abundant in the Morrison formation and are frequently found as loose fragments wherever this formation has been exposed to erosion. Occasionally vugs are found in the chert which are lined by well crystallized transparent quartz crystals up to three-quarters of an inch in diameter. In color these concretions are usually a milky gray, but vary into a deep brownish black. The weathered surfaces show a decided tendency towards granular structure, although the mass of the concretion is dense and apparently homogeneous. Occasionally a concretion is found which shows a tendency toward oolitic structure. One in which this was especially well developed was thin sectioned and studied under the microscope. This specimen is from the vicinity of Sturgis and is a gray to bluish black dense chert, with exceedingly irregular, rough and deeply pitted weathered surfaces. Spherical ooles up to two millimeters in diameter are visible.. With the exception of a few pores filled with calcite or yellow clay, the specimen is very dense. The fracture is conchoidal and takes place readily across the ooles, which show up in rounded, irregular cross sections of a somewhat lighter color than the cement. Concretionary structure is not apparent in them, except that a darker nuclear portion is at times visible. Only rarely does an oole break out into relief, when it shows as a small white to gray sphere of chalcedony-like material.

Under the microscope, the specimen proves to be dense, cherty material predominently, with some fibrous chalcedony filling. The separate ooles are very irregular in outline and in size. Their greatest diameter varies from 2 mm. down to .1 mm. The cross sections are quite variable, practically no true spherical outline being noticeable. Many have semi-angular outlines with well rounded corners. Usually the outer edge tends to be an irregular, slightly undulating line, sharply terminated by the interstitial cement. The ooles are dense chert arranged in fine mosaic. Concentric structure is only faintly visible, shown by a slight darkening of the central zone. Well defined concretionary structure is only apparent in a few grains, although many have a light layer of chalcedony on the outside of the chert oole proper, which is differentiated from the chalcedony cement.

The cementing material is finely fibrous chalcedony, which also fills several vugs with beautifully radiating crystals. It is often arranged in well defined layers running parallel to the interstitial boundaries. Much of the cement when studied under high magnification (x200), shows a peculiar crinkly and lobate arrangement, strongly suggesting a cross section through the top of a truffle. Several vugs in the specimen have been completely filled by fibrous chalcedony radiating out from several centers and forming imperfect spherulites. These show under cross nicols a sharp interference cross. The boundary between the fibers in adjacent centers is in every case a line concave towards the nearer center of radiation, providing that the length of radius of the sphere is proportional to the time of its growth.

Mr. N. H. Darton of the U. S. Geological Survey has been kind enough to send the writer a piece of oolitic limestone occurring in the Morrison formation near Sturgis which will be more fully described under calcite. In appearance the oolitic chert and limestone are so nearly alike that the author believes the former to be due to a replacement of oolliis limestones by silica bearing solutions. The silica was probably derived from minute skeleton remains of foraminifera disseminated through the calcareous layers in the Morrison formation.

12. Flint. This variety varies from a gray to a brown to a black color, is usually dull in luster, and if exposed to weathering is surrounded by a thin powdery white layer which is very soft. It has a deep conchoidal fracture, breaking with a sharp edge and hence formed the favorite material for the arrow heads of the Indians.

13. Jasper. The term jasper is applied to dense weakly translucent varieties of quartz bright red, yellow or

brown in color, and usually with vitreous luster. In the southeastern Black Hills, near Buffalo Gap, we find a conglomerate made up of small rounded jasper pebble cemented by quartz. The rock is dense and hence capable of taking a high polish. Its beauty is enhanced by the highest colors of the red, brown and even purple jaspers set in the grayish white matrix. For these reasons it is a favorite stone for ornaments such as paper weights, and representative specimens may be found in most mineralogical museums in the United States.

In addition to the above we find quartz as the main ingredient in most sandstones, ,gravels and conglomerates. Shales and slates are made up to a large extent of finely triturated grains of silica. It is a very common mineral in igneous rocks such as granites, rhyolites, pegmatites, etc., and is common in many metamorphic rocks, as for example schists and gneisses.

In many localities within the Black Hills area we get petrified wood. This in nearly every case is due to the replacement of the original wood tissue by an impure silica. Thus most of the petrified wood is chert and is usually so dark in color that even polishing does not bring out the original structure.

46. OPAL (SiO_2nH_2O).

This mineral is a silicon dioxide containing varying amounts of water. Hess and Wells (103) mention opal as occurring in the pegmatite of the Etta claim. This appears to be a secondary product formed by the alteration of other minerals. It is not described. A variety of quartz approaching opal in characteristics is found with some of the silicified wood in the Lakota formation.

47. ARSENOLITE As_2O_3.

Specimens of leucopyrite (FeAs) from the Etta Mine show a white pulverulent coating of this mineral. Optical tests prove this coating to be isometric. It has a strong sweetish and astringent taste. Upon heating it volatilizes, yielding dense white fumes and giving the odor of garlic. Arsenopyrite also frequently shows these powdery coatings of an arsenic oxide, wherever it is exposed to weathering. This is quite prominent at the White Spar Mica Mine near Custer.

48. CLAUDEDITE As_2O_3.

This form of arsenic oxide differs from arsenolite in crystal form only, occurring in the monoclinic system. This is reported to occur in some abundance near Spokane by Dr. Herman Reinbold (personal communication).

49. BISMITE $Bi_2 O_3$.

This oxide of bismuth occurs as an earthy coating or minute nodules of white to pale yellow color associated with bismuth minerals such as tetradymite ($Bi_2 Te_3$), bismuthinite ($Bi_2 S_3$) and native bismuth from which it is derived by weathering. Thus it occurs at the Cobalt Lode north of Bismuth and on several gold-telluride veins northeast of Custer. It is usually friable or powdery. Nodules are very soft and quite heavy (Sp. Gr. —4.1). The luster is dull. The nodules are quite easily fusible and are soluble in nitric acid. On dilution with water, however, there is a heavy white precipitate of basic bismuth nitrate.

50. TELLURITE TeO_2.

Minute capillary tufts, practically of microscopic size, of this mineral were observed on a single specimen of decomposed gold telluride ore from a quartz vein (exact locality ?) northeast of Custer. The fine hairs were a gray color, and were quite transparent. Dissolved in sulphuric acid they yielded a peach red colored solution.

51. MOLYBDITE (MoO_3).

Occurs as an earthy straw yellow powder on molybdenite from which it is derived by oxidation. Found in minute amounts in the Harney Peak district.

52. CERVANTITE (Sb_2O_4).

This antimony oxide occurs as a decomposition product on stibnite and on some of the lead antimony sulphides of the central Hills. It is usually a pale yellow to white pulverulent coating shown in irregular spots. It has a dull luster. When highly heated it is completely volatilized, but without burning and without giving the sulphur odor, which will distinguish it from native sulphur and from molybdite (MoO_3), similar in color and appearance. The mineral association will also give a valuable clue as to the probable identity of the yellow coating. Occurs near Hill City, Rochford, Mystic, Silver City and Sheridan.

53. CUPRITE (Cu_2O).

The red oxide of copper is found in some of the copper prospects of the Hills in minute amounts associated with malachite ($CuCO_3Cu(OH_2)$) and azurite ($2CuCO_3$ $Cu(OH)_2$). It is an alteration product formed by the oxidation of copper sulphides. In the Bear Lodge district cuprite is found in small amounts associated with chrysocolla ($CuSiO_3.2H_2O$) and tenorite (CuO). Cuprite varies in luster from a dull to an adamantine. The color is usually a dark red, the streak, brownish red. Has a conchoidal fracture. Crystals are isometric, octahedrons are common, but none are known from the Black Hills. The hardness is about 3.5 and the specific gravity about 6. It is easily confused with hematite (Fe_2O_3) which may be distinguished by its greater hardness (5.5). Scott (44) mentions it as occurring on the South Fork of Box Elder Creek, and at the Queen Mine west of Fairburn.

54. ZINCITE (ZnO).

This mineral is mentioned by Scott (44) as determined by Prof. Jensen and occurring in the vicinity of Custer, etc. No specimens have come to the attention of Dr. O'Harra nor of the writer. Its occurrence in the Black Hills is to be doubted.

55. TENORITE (CuO).

Black copper oxide is also a decomposition product formed by the oxidation of copper sulphides. It is frequently associated with the chrysocolla in the Bear Lodge district and is said to occur in the Blue Lead Mine at Sheridan, at Harney City, and also on Lightning Creek. This mineral is usually dull or earthy in luster, and associated with chrysocolla ($CuSiO_3.2H_2O$) or malachite $CuCO_3.Cu$

$(OH)_2$ as massive minerals or as green stains. Tenorite is hard (5). It gives a black streak and usually soils.the fingers.

56. CORUNDUM (Al_2O_3).

This mineral has been reported from the Bad Lands and is mentioned as occurring there by Dana*. It has also been reported as occurring in association with cassiterite and columbite in the Harney Peak district and more especially the Etta vein. The experiments of Morozewicz** seem to show that corundum can only form in fusions containing no free quartz, but that as long as silica is present, the latter will combine with alumina (Al_2O_3) to form a silicate ($Al_2O_3SiO_2$). This is also in harmony with all well authenticated occurrences of corundum, which usually is formed in granular limestones, in schists, in syenite pegmatites, in dunites and peridotites, etc., but never in igneous rocks so rich in quartz as the pegmatites of the Hills. A number of specimens of supposed corundum sent to the School of Mines for identification from the Harney Peak district proved to be andalusite ($Al_2O_3.SiO_2$). Thus we should eliminate corundum as a mineral accessory in the tin deposits or at least regard it as of very doubtful occurrence.*

Scott (44) mentions the finding of sapphire in Sunday Gulch and the occurrence of a single specimen of ruby in the gravel of Iron Creek, Custer County as identified by Jensen. In all probability the identifications are not reliable and spinel or beryl was probably confused with corundum.

Nothing is known regarding the reported occurrence of corundum in the Bad Lands. Dr. O'Harra, who is more familiar with the geology and mineralogy of the Bad Lands than any one else, informs me that no specimen has ever come to his attention. No locality was given in the above citation. There is a possibility for its occurrence, however, and hence a brief general description will be given of corundum.

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*A System of Mineralogy, VI ed. p. 1088 (J. S. Murphy notes).

**Experimentelle Untersuchungen uber die Bildung der Minerale in Magma.

*During the field season of 1913, the author made a careful search for corundum in a number of pegmatites, but none was found.

Corundum crystallizes in the hexagonal system, usually in rounded prisms, frequently in rhombohedra. The three oxides corundum (Al_2O_3) hematite (Fe_2O_3) and ilmenite $(FeTi)_2O_3$ have analogous compositions and since their crystal forms and axial ratios are practically the same, they are often collectively referred to as the corundum group. Corundum has an adamantine to vitreous luster, is the hardest mineral in nature, with the exception of diamond, and has a specific gravity of about four. Corundum has excellent basal and rhombohedral cleavage, and along the cleavage planes tends to alter to micaceous minerals which are soft, hence care must be taken to try a fresh surface for hardness.

Corundum occurs in the following varieties:

(a) Common corundum—dark and dull colored, and not transparent crystals or masses.

(b) Precious corundum—transparent to translucent bright colored varieties. Sapphire, blue; Ruby, red; Oriental Topaz, yellow; Oriental Emerald, green. Very valuable if clear.

(c) Emery—impure granular corundum mixed with iron oxides (hematite (Fe_2O_3) or magnetite (Fe_2O_3FeO)).

57. HEMATITE (Fe_2O_3).

This mineral is the great ore of iron and is one of the most widely distributed minerals in nature. In small amounts it may be found practically anywhere. In crystallization it is analogous to corundum, occurring in rhombohedra especially. Such crystals are not known from the Black Hills.

Hematite varies from a dull to a metallic luster, and varies in color from red into brown into black. The streak is very characteristic and is usually a bright cherry red or a decided reddish brown. In hardness it varies up to 6.5 for the black colored variety. The specific gravity is usual-

EXPLANATION OF OPPOSITE MAP.

Tin Claims.

1. Tin Hill.
2. Glendale.
3. Samelias.
4. Cowboy.
5. Coates.
6. Gertie.
7. Carnbray.
8. Snowshoe and Tin Belle.
9. Blue Bird.
10. Olymphia.
11. Tin Plate Group.
12. Sally Cavanaugh.
13. Tin City.
14. Naiad Queen.
15. Deacon Wright.
16. Tin Queen.
17. Louise.
18. Tenderfoot Group.
19. Old Jeff.
20. Annie.
21. Tin Boom.
22. Mohawk.
23. Cassiterite.

Tungsten Claims.

24. Black Metal.
25. Good Luck.
26. Great Wonder.
27. Wolram (B.H.T.M.M. Co.)
28. Vida May.
29. Petits.
30. Wolfram.
31. Reinbold.
32. Petits Ferberite.

Lithium Claims.

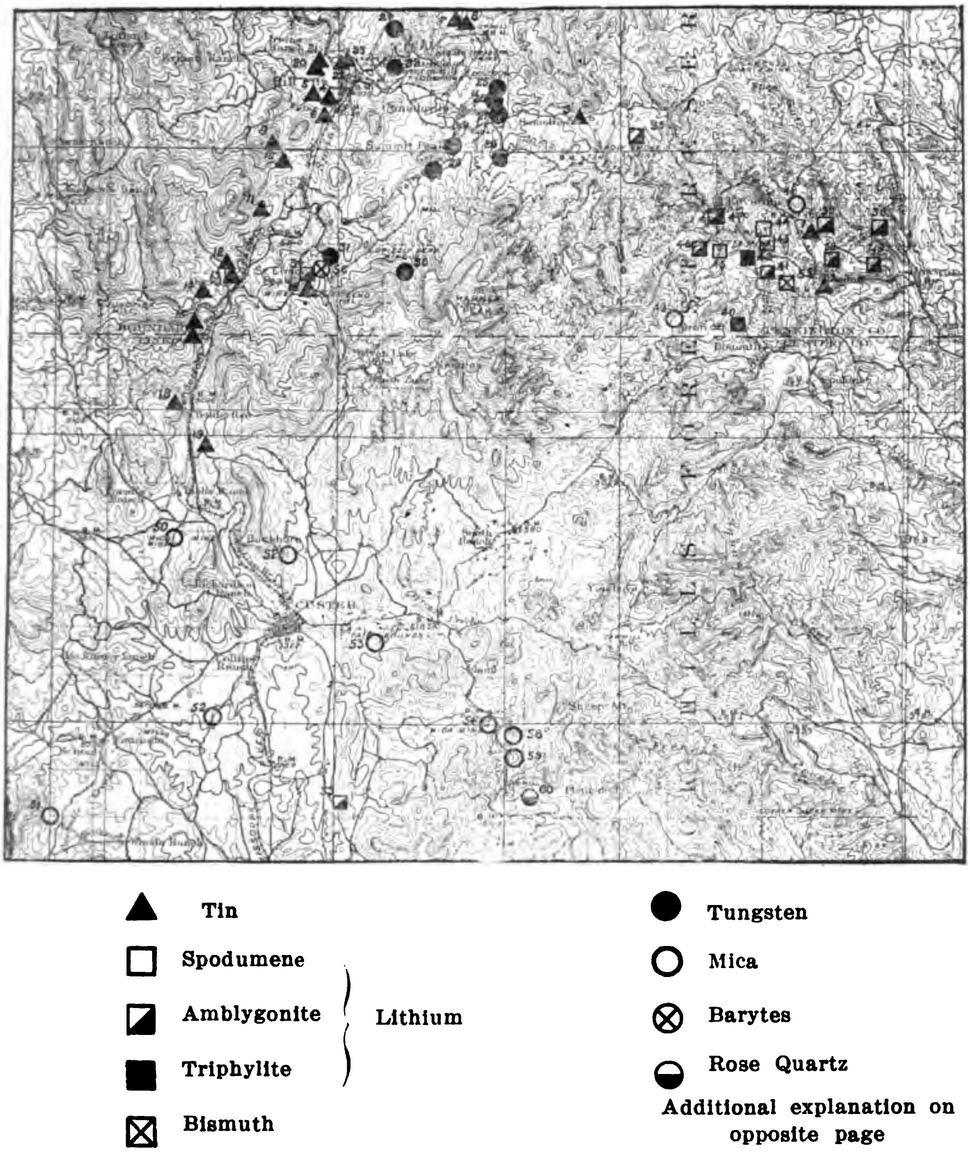
33. Bond.
34. Tin Queen.
35. Bob Ingersoll.
36. Tiger.
37. Nichols.
38. Wood Tin.
39. Cobalt (Margaret).
40. Dyke.
41. Equality.
42. King Mica.
43. Swanzey.
44. Bull Conn.
45. Etta.
46. Hugo.
47. Peerless.

Mica Claims.

48. Everley.
49. Jenssen.
50. Crown.
51. New York.
52. White Spar.
53. Climax.
54. Cooks.
57. Lost Bonanza.
58. Russell.
59. Window Light.

Miscellaneous.

55. Reinbold (barite).
56. Cobalt (bismuth).
60. Scott (Rose quartz).



Additional explanation on opposite page

Map of the Harney Peak Region Showing the Important Economic Deposits Genetically Connected with the Harney Peak Granite. (Based on U. S. G. S. Topographic Map.)

ly about 5, although earthy varieties may go as low as 4.

We have the following varieties in the Black Hills:

(a) Specular hematite or specularite. This has a decided metallic luster and a steel gray to iron black color. It is usually foliated or micaceous in structure and is hence called micaceous hematite. In fine fragments it is often magnetic. Such micaceous hematite occurs in some of the quartz-pegmatite veins in the Harney Peak region. A specimen from there in the School of Mines collection shows a pegmatite consisting of microcline, varying up to one inch in diameter, small quartzes and very fine grained specular hematite, traversed by a banded quartz vein, consisting of coarse (up to ½ inch) flakes of specularite arranged along either wall often in radiating aggregates, capped by coarsely crystalline milky quartz projecting and interlocking in the center. On Box Elder Creek (1 p. 57) specular hematite occurs in profusion in thin bands interlaminated with siliceous slates or milky quartz. The hematite is micaceous, well crystallized, but usually in layers never over several inches in thickness. The whole deposit is about 800-1000 feet in thickness, but owing to its high siliceous character of no value as a source of iron ore. Micaceous hematites also occur at Hat Mound ten miles northwest of Rapid City. At Hat Mound some of the specular hematite is exceedingly fine grained, micaceous and dense.

(b) Oolitic hematite. This is an earthy variety made up of minute concretions of hematite, so that the mass suggests in appearance the roe of fish. This variety occurs frequently in the top of the Cambrian Strata, the Deadwood formation. They are never in any large quantities, although they are very noticeable on account of the red color of the enclosing rocks. They are earthy and soft. Analyses of such oolitic specimens gave Prof. M. F. Coolbaugh the following results:

	1.	2.	3.	4.
Fe=	41.25%;	26.14%;	41.88%;	45.87

A typical sample from the top of the Deadwood, west of Rapid City, on Rapid Creek, gave Prof. Coolbaugh the following:

Silica (SiO_2)	33.10
Alumina (Al_2O_3)	17.28
Ferric Oxide (Fe_2O_3)	30.32
Lime (CaO)	3.17
Magnesia (MgO)	.51
Phosphoric oxide (P_2O_5)	2.96
Sulphur trioxide (SO_3)	.54
Potash (K_2O)	6.33
Soda (Na_2O)	.31
Ignition loss	5.23
	99.75

This well shows the impure nature of the materials. Undoubtedly picked specimens could be found running well above 65% in iron and approaching the theoretical. This variety tends to grade into an impure soft and earthy one, styled red ocher.

(c) Compact varieties. These are usually massive and columnar or radiating. They vary from black to brown to red in color and tend to grade over into earthy ocherous varieties with which they are frequently associated. In fact most iron deposits are mixtures of not only the different varieties of hematite, but also of limonite ($2Fe_2O_3.3H_2O$) as well.

Ten miles west of Rapid City near Hat Mound is a deposit of hard dense red and also black micaceous hematite. This contains small amounts of magnetite. Analyses yielded the following results (95):

	Average Ore.	Fine grained red hematite.
Ferric oxide	84.05%	98.35%
(Iron 58.84%)		(68.85%)
Silica	11.22	.43
Alumina	3.38	....
Phosphor pentoxide	.801	trace
Sulphur	.08	....
Manganese dioxide	trace	....
Lime	trace	....
Magnesia	trace	....

Immediately northwest of Hayward we have a deposit of soft red hematite. (See analysis (1) below.) At Iron Mountain, 3 miles south of Keystone we get an iron ore deposit consisting of a porous black hematite which has the characteristics of the gossan of a pyrite vein (65). (See analyses II., III., IV. and V.)

Iron deposits of minor importance are known elsewhere.

Analyses of Iron Ores.

	I.(a)	II.(b)(1)	III(b)(2)	IV.(a)	V.(a)	VI.(c)	VII.(c)	VIII.(c)
Iron	50.30	55.40	60.43	48.09	52.26	59.71	55.23	59.35
Silica	17.70	7.41	6.24	23.66	12.53	10.10	12.46	8.43
Alumina	trace	1.46A1	.36A1	.26	----	----	----	----
Phosphorous	.15	.88	.34	(P2O5) .301	(P2O5) .222	.23	.168	.2
Manganese oxide	trace	1.97Mn	2.56Mn	trace	----	----	----	----
Sulphur	.17	----	----	.25	.16	.33	1.27	.18
Lime	1.08	1.21	.95	.42	----	----	----	----
Magnesia	trace	.47	.35	trace	----	----	----	----
Moisture	----	9.60	10.06	----	----	----	----	----

(a) Analyses by Cooledge & Overpeck, Thesis, S. D. School of Mines, 1908.

(b) Analyses furnished by Mr. Samuel Scott, see 65, p. 62.

(c) Analyses by Prof. M. F. Coolbaugh.

(1) Also copper .41 organic & vol. matter 3.12.

(2) Also organic & vol. matter 2.07. A series of three hundred assays yielded $3.10 of gold and ½ ounce of silver per ton.

In most of the above ores as has been stated before limonite ($2Fe_2O_3.3H_2O$) occurs in intimate association with hematite so that usually no mechanical separation of the two is possible. No iron ores are at the present time produced in South Dakota, although some of the iron ores have been ground and used in the manufacture of mineral paints.

58. ILMENITE $(FeTi)_2O_3$.

This mineral is also included as a member in the corundum group having composition, crystal form, and axial ratio closely similar to corundum and hematite. No crystals are known so far from the Black Hills only thin plate-like or sheet-like intergrowths in milky to clear quartz in the Harney peak district. The plates are an iron black color, have a metallic luster, and a brownish black streak. The plates are often curved and are usually parallel to each other. Their hardness is 6 and their specific gravity 4.6. Ilmenite has no apparent cleavage, but conchoidal fracture showing in small faces. Its lack of magnetism will distinguish it from magnetite ($FeO.Fe_2O_3$) with which it is readily confused. It occurs in the Tin Queen (96), the King Mica, the Tiger and other claims.

59. SPINEL ($MgO.Al_2O_3$).

This mineral is also used as the type mineral for a group, the spinel group, representatives of which found in the Hills are spinel and magnetite ($FeO.Fe_2O_3$).

Spinel occurs in isometric crystals, usually octahedrons, rarely in cubes. It has an imperfect cleavage parallel to the octahedron face. It is brittle. The hardness is 8, and the specific gravity about 3.7×. The luster is usually vitreous to adamantine. Pink spinels are the more common, although brown, black, green, yellow and violet colored specimens are known. If they are transparent and pure in color they are valuable as gems.

None are on hand from the Black Hills, but they have been reported from the pegmatites and marble of the Harney Peak district.

60. MAGNETITE ($FeO.Fe_2O_3$).

Magnetite is often loosely spoken of as magnetic iron ore because it is strongly attracted by the magnet. Certain magnetites naturally possess polarity and are enabled to attract bits of iron and steel. These varieties are lode stone.

Magnetite occurs in isometric crystals, especially octahedrons of small size in some abundance in the vicinity of Nemo on Box Elder Creek. It also occurs near Greenwood and Welcome City (44), and as a microscopic constituent is common in most of the igneous and many of the metamorphic rocks of the Hills.

Magnetite is blue black in color, has a metallic luster, fair octahedral cleavage, and a black streak. Its hardness is 6.5 when unaltered, and its specific gravity 5. Its color, streak, and strong magnetic properties will distinguish it from its confusions, especially ilmenite [$(FeTi)_2O_3$] and specular hematite (Fe_2O_3).

THE RUTILE GROUP.

The minerals cassiterite, rutile, tapiolite, and struverite and others not known from the Black Hills have recently been shown by Schaller* to be the members of an isomorphous group.** Close relationship crystallographically as indicated by similarity in axial ratios, common forms and twinning laws, and the close chemical relationship are points in favor of this conclusion.

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*Schaller, Waldemar T. Mineralogical Notes, Series 2. U. S. G. S. Bull. 509.

Schaller considers that the members of this group are are all derived from six primary compounds by combinations in various ways. The six primary compounds are:

a. Ferrous columbate $Fe(CbO_3)_2$
b. Ferrous tantalate $Fe(TaO_3)_2$ Tapiolite
c. Ferrous titanate $Fe(TiO_3)$.
d. Titanyl titanate $(Ti(TiO_3)$ Rutile
e. Stanyl stannate $(SnO)(SnO_3)$ Cassiterite
f. Ferrous stannate $Fe(SnO_3)$

Only compounds b, d and e occur pure in nature and are known as tapiolite, rutile, and cassiterite respectively.

Struverite is considered to be an isomorphous mixture of more than two of these primary compounds. Thus the Black Hills struverite is made up of 25 parts ferrous columbate, 81 parts ferrous tantalate, 306.5 parts titanyl-titanate, and 4.5 parts stanyl stannate. Schaller believes that ilmeno-rutile and struverite are the same and that the former term should take precedence.

61. CASSITERITE $SnO.SnO_3$.

The formula is more frequently written SnO_2, but the tendency lately has been to use the above expanded form and consider the mineral a stanyl stannate rather than a tin dioxide. Cassiterite was first identified from the Black Hills by Dr. Richard Pearce in 1876 as stream tin in the gold dust from the Northern Black Hills (65). In 1877 it was discovered in the Southern Black Hills on Elk Gulch*.

As soon as its occurrence was definitely known, widespread interest was aroused and consequently vigorous prospecting followed. Soon it was reported from many different localities throughout the Southern Hills and also from the Tinton or Nigger Hill district about forty miles west of Deadwood on the Wyoming line. The expectations of hav-

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**Zircon ($ZrSiO_4$) is also probably a member of this group.

*For a discussion of Cassiterite from the economic standpoint, the reader is referred to bulletin No. 6, S. D. School of Mines, "The Mineral Wealth of the Black Hills," by Dr. C. C. O'Harra.

ing a great tin producing district were strengthened by over-capitalization of companies and by over-estimates of the richness of the ore available. For a few years there was vigorous activity in the exploitation, but due to legal complications the largest tin mining company went into the hands of a receiver and practically nothing beyond assessment work has been done on any of the claims within the last ten or twelve years. Many claims, however, merit careful examination and sampling, as the ore would seem to be sufficiently rich to pay for mining under judicious management. Undoubtedly in the future activities will be resumed under the stimulus of the high value of tin.

Cassiterite occurs in the tetragonal system. No well defined crystals seem to occur in the Black Hills. The faces are usually rough and striated and the crystals are very frequently broken. On the whole the cassiterite from the Tinton district occurs in better crystals than that in the Southern Hills, although the grains do show more shattering and hence make an identification of the forms very difficult. The forms present fall in one of two groups:

a. Prismatic, usually showing the two prisms (1a:1a:c) (1, 0, 0) and 1a:1a:αc) (1, 1, 0). Terminations are indistinct, but apparently the common pyramids (1a:1a:1c) (1, 1, 1) and (1a:αa:1c) (1, 0, 1) are present.

b. Pyramidal forms—apparently made up of a more acute pyramid than either of the above, probably (1a:1a:2c) (2, 2, 1)?, but no accurate measurement was possibe. Hess (95) mentions a twin from the Nigger Hill district in which the two individuals made angles of 90° with each other. Blake (12a) mentions pyramidal twins of cassiterite from the George Coates lode near Hill City. Such also occur in the Bob Ingersoll.

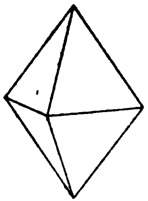

Fig. 46.
Cassiterite.

Usually the cassiterite occurs in rough elongated prismatic forms with no definite planes apparent or more commonly as minute grains varying in size up to irregular masses 60 and even 100 pounds in weight. The latter are however, rare. The physical characteristics may be discussed from the standpoint of origin and occurrence. Thus we may classify cassiterite occurrence in the Black Hills as follows:

I. Primary Cassiterite, i. e., an original constituent.
  a. In true pegmatites.
  b. In albitic muscovite granite.*
  c. In quartz veins.

II. Secondary Cassiterite, i. e., a result of secondary deposition.
  a. In placers.
  b. In veins and dikes.

III. Cassiterite in contact metamorphic rocks, greisens, etc.

Primary Cassiterite Occurrences.

a. In true pegmatites.

Under pegmatites I mean to include those dikes or vein-like masses consisting essentially of such minerals as quartz, albite, microcline, muscovite and accessory amounts of rarer minerals such as spodumene, lepidolite, apatite, amblygonite, beryl, etc., which are characterized by very coarse crystallization and by showing much variation in mineral composition throughout their extent. In these the cassiterite is present in minute grains and also in masses attaining 50 and 60 pounds in weight. Examples of such occurrences are the Etta Knob, the Bob Ingersoll, the Peerless and others in the Harney Peak region, and the more important claims of the Nigger Hill district. In these the cassiterite varies in color from a quite light gray to an iron black. The gray colored cassiterite has a true metallic luster and is usually in fair sized grains half an inch or more in diameter, while the black grains are usually small, the size of a mustard seed or pea, and have a brilliant adamantine luster. The cassiterite is usually segregated in bunches or shoots in the pegmatite and never uniformly distributed. These segregations are usually nearer one wall or nearer the narrower portions of the dike (29). The streak of the cassiterite is usually very pale brown or gray, but the powdered cassiterite of the Nigger hill district is a purplish color, as is also the cassiterite from the several claims near Harney Peak, as for example the Black Metal and the Tin Queen. The specific gravity varies from 6.7 to 7 and is reduced by the admixtures of the titanium or iron niobate molecule isomorphous with the cassiterite. That the cassiterite is a true constituent mineral of the pegmatite is shown by its relationship to the other minerals.

b. Primary cassiterite in albitic muscovite granite.

As noted above, the pegmatites vary quite decidedly in character and frequently they grade into medium grained rocks made up in the greater part of muscovite and albite, accompanied by more or less quartz. There is a tendency towards equal development of grains none of which will exceed one inch or one and one-half inch in diameter. Here the cassiterite is present in small grains occupying the interstices between the other minerals, when it is quite black in color and fairly evenly distributed through the rock, or occurs as included grains in the albite, rarely in microcline, when the color of the grains is quite dark brown. Such ore occurs in the Gertie, the Coates, the Carnbray and other claims in both districts. Cassiterite occurring in this manner is frequently associated with black tourmaline, columbite, stuverite and tapiolite. All these minerals when granular resemble the tin mineral so closely that they lead the prospector to over-estimates as to the richness of the ore which is frequently too low in tin content to be of any value.

c. Primary cassiterite in quartz veins.

Very frequently both in the Harney Peak and in the Tinton district quartz veins tend to accompany the pegmatites. These usually consist of milky quartz, often carry arsenopyrite and loellingite, and more rarely wolframite. At times tetradymite and sylvanite occur in these veins associated with native gold, as for example near Custer and Keystone. Occasionally cassiterite is found in these veins scattered in small brown and somewhat resinous grains through the milky quartz. Such cassiterite grains occur in the Tinton district, and in the Harney Peak district in the Forest City claim, the Tin Boom No. 1 and No. 2, the Mohawk, the Ottumwa, the Samelias No. 3, et al. This type has a pale yellow streak, if disseminated is light brown in color. Occasionally cassiterite occurs in rough banded streaks or pockets when the color is dark brown. The specific gravity of the cassiterite is 7.02 and of the Black Hills occurrences appears to approximate more closely the ideal composition, $SnO.SnO_3$.

II. SECONDARY CASSITERITE.

a. Cassiterite in placers.

As the different tin deposits are exposed to weathering they are broken down and distintegrated and the loose material is transported away into the gulches and creek beds by the action of running water. Cassiterite is a very resistant mineral and does not decompose, hence is concentrated with other heavy minerals in pockets and streaks through gravels which we call placers. Any of the streams in the Harney Peak and the Tinton district may show such tin deposits, but the more important are Battle Creek, Iron Creek, and Spring Creek in the Southern Hills, and Sand Creek and Bear Gulch on the Wyoming line in the Tinton area. The cassiterite is associated with garnet, hematite (slickers), ilmenite, gold, columbite, tantalite, tourmaline, scheelite, wolframite, monazite, zircon, barite, beryl and other minerals of less interest. The cassiterite is usually in small grains (although specimens up to five pounds in weight have been found) which may or may not be rounded, depending upon the distance they have been transported. The grains are usually black in color, but are also grey or brown. The streak is quite variable from a practically colorless to dark brown. The hardness is somewhat less than that of cassiterite found in place which may be due to slight alteration on the surface or more probably to a thin coating of some foreign substance. The specific gravity of the stream tin varies from 6.6 to 6.96. A peculiarity shown by the analyses of the stream tin is that it seems to be less pure in SnO_2 content than the cassiterite from which it has been derived (14).

This may, however, be due to the admixture of such heavy minerals as columbite, tantalite, and tapiolite (64), but can more probably be accounted for as caused by the deposition of a thin coating of limonite ($2Fe_2O_3.3H_2O$) on the exposed grain, which will also explain the lack in hardness of the outer surface of the stream tin. Thus if we thoroughly wash a grain of stream tin in water, then boil it in hydrochloric acid, we can obtain a decided test for ferric oxide. Since cassiterite itself is insoluble in acids this iron oxide must be a secondary coating.

There is no mining going on for stream tin, although some is saved in intermittent placer mining for gold along Sand Creek, and shipped occasionally.

b. Secondary cassiterite in veins and dikes.

Cassiterite, as has been stated before, is one of the most insoluble of minerals and secondary concentration is hence practically negligible. Stannite, the sulphide of copper, iron and tin, which has been previously described, is, however, readily decomposed, yielding as a prominent alteration product cuprocassiterite, a hydrous tin copper oxide. This, of course, is easily soluble and under proper conditions may precipitate SnO_2 again as Cassiterite and remove it from the more soluble copper. Thus many of the large masses of casiterite found in the Etta and Peerless suggest secondary growth and in many cases partly replace accompanying minerals. Blake (12a) describes a cassiterite mass which replaces half of a spodumene crystal. Along the cleavage planes of many spodumene crystals occur small radiating groups of cassiterite crystals arranged usually in small circular rosettes which are often transparent and vary from pale yellow to dark brown in color. In other specimens, cassiterite occurs as a dark brown translucent coating always along the cleavages or the crystal faces. Many muscovite crystals show the same type of thin plates and rosettes of cassiterite and wherever observed they are flattened between the cleavages or along the outer edges of the grains. This type of cassiterite undoubtedly results from the deposition of SnO_2 from circulating solutions.

III. CASSITERITE IN CONTACT METAMORPHOSED ROCKS.

When rocks are cut by igneous intrusions such as the granite of the Harney Peak district, they are acted upon by heat and pressure and also by the solutions coming from the hot igneous rocks. As a result the boundaries between the intruded and the intrusive rock are frequently changed more or less, often profoundly. This change we call contact metamorphism. A little cassiterite occurs in such rocks usually accompanied by tourmaline, muscovite and quartz. This contact effect is never well developed nor important as far as tin occurrence is concerned. Usually not more than a few inches of the intruded rock are effected. When intrusion is in granite the tendency is to produce a narrow zone enriched in muscovite, quartz and tourmaline, with a little tin along the border. Such a rock may be called a greisen. This is especially well developed in the Glendale. In mica schists there is a frequent enrichment of small tourmalines and minute grains of struverite, tapiolite and cassiterite. In other cases there is an enriched zone of graphite along the wall several inches in thickness accompanied by a few grains of cassiterite. A little arsenopyrite frequently accompanies such tin occurences. All of these are of no economic importance, and only possess mineralogical interest.

COMPOSITION.

The following analyses represent typical Black Hills occurrences:

	I.	II.	III.	IV.	V.
SnO_2	94.36	98.22	98.13	96.08	96.42
Fe_2O_3	1.80	.72	.43	1.90	....
Ta_2O_5	2.42	....	....	....	....
SiO_2 (Insol.)	1.00	.64	1.40	.88	3.58
Ignition	...	.34	....	.12	....
	VI.	VII.	VIII.	IX.	X.
SnO_2	97.50	94.70	92.60	92.80	93.00
Fe_2O_3	...	....	....	....	2.16 Fe
Ta_2O_5	...	....	....	....	....
SiO_2 (Insol.)	...	....	....	....	3.90
Ignition	...	....	....	....	....

I.=Etta Mine, largest mass found. Headden (86).

II. and III.=Samelias claim, brown cassiterite. Headden (86).

IV.=Herbert's placer, Pennington county. Headden (86).
V.=Occidental Mine. VI.=Tin Mountain Mine.
VII.=First Find. VIII.=Nigger Hill Stream Tin.
IX.=Southern Hills stream tin. X.=Nigger Hill stream tin.
V, VI, VII, VIII, IX and X all by Headden (15).

The first analysis is recalculated by Schaller (106) showing this particular mineral to be made up of 5 parts (2.5%) of ferrous tantalate Fe $(Ta_2O_3)_3$ 18 parts (4.1%) of ferrous stannate ($FeSnO_3$) and 303.5 parts (93.3%) of stannyl stannate ($SnO.SnO_3$). Analyses II. and III. indicate a closer approach to the ideal stannyl stannate (cassiterite) with about 1% of ferrous stannate. Analyses IV., VIII., IX. and X. all of stream tin show the decrease in tin content commented upon previously.

CONFUSIONS AND MEANS OF DISTINCTION.

The following minerals may occur in association with cassiterite and are frequently mistaken for this mineral. Columbite, tantalite, tourmaline, wolframite, ilmenite, hematite, and more rarely struverite and tapiolite. It is very easy to reduce cassiterite to native tin; a fusion of equal parts of charcoal and cassiterite with 4 or 5 volumes of soda will suffice and can easily be performed in an ordinary assayer's furnace. If this is not available the determination had best be left to a mineralogist or a chemist.

Associations: The following list of minerals associated with cassiterite is compiled from the literature on that subject and also from the many specimens at present in the museum of the State School of Mines:*

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*For a more complete and thorough discussion see article in Ec. Geol. March, 1914, "The Differentiation of a Granitic Magma from the Standpoint of the Paragenesis of the Minerals of the Harney Peak Granite," by Victor Ziegler.

MUSCOVITE GRANITE	PEGMATITES	QUARTZ VEINS	CONTACT META.	PLACERS.
Albite	Albite			
Almandite	Almandite		Almandite	Almandite
Arsenopyrite		Arsenopyrite		
Apatite*	Apatite		Apatite	Apatite
	Arsenopyrite		Arsenopyrite	
	Autunite	Autunite		
	Andalusite	Andalusite		
		Barite		
	Amblygonite			
	Biotite	Biotite	Biotite	Biotite
	Beryl			Beryl
	Bismuth	Bismuth		
	Bismuthinite	Bismuthinite		
Cassiterite	Cassiterite	Cassiterite	Cassiterite	Cassiterite
	Chalcopyrite	Chalcopyrite		
	Chalcocite	Chalcocite		
	Chlorite	Chlorite		
	Ferberite	Ferberite		
	Fluorite	Fluorite		
	Galena	Galena		
	Graphite	Graphite	Graphite	
	Griphite			
	Grossularite		Grossularite	Grossularite
	Gold	Gold		Gold
Hematite (Spec)	Hematite (do)	Hematite (do)		Hematite
		Huebnerite		
Ilmenite	Ilmenite	Ilmenite		Ilmenite
Lepidolite	Lepidolite			
	Loellingite	Loellingite-Leucopyrite		
	Melanite		Melanite	Melanite
Microcline	Microcline			
	Molybdenite	Molybdenite		
	Monazite			Monazite
Muscovite	Muscovite	Muscovite	Muscovite	
Oligoclase	Oligoclase			
Orthoclase	Orthoclase			
	Petalite			
Pyrite	Pyrite	Pyrite	Pyrite	
	Rutile	Rutile		
Quartz	Quartz	Quartz	Quartz	Quartz
	Scheelite	Scheelite		Scheelite
		Siderite		
Spinel*	Spinel			Spinel
	Spodumene			
	Stannite	Stannite		
*	Spessarite		Spessarite	
Struverite	Struverite			Struverite
		Sylvanite		
			Staurolite	
Tantalite	Tantalite			Tantalite
Tapiolite	Tapiolite			Tapiolite
		Tetradymite		
Titanite*	Titanite			
	Triphylite			
	Triplite			
	Torbernite			
Tourmaline	Tourmaline	Tourmaline	Tourmaline	Tourmaline
	Wolframite	Wolframite		
Zircon*	Zircon			Zircon

(The minerals starred are usually microscopic in size for the particular occurrence.)

In addition to the primary minerals above enumerated we also have the following occurring as decomposition products above the ground water level usually:

Arsenolite
Arsenostrengite
Bismite
Bismutite
Cacoxenite
Calcite
Chlorite
Claudedite
Cuprocassiterite
Diadochite
Dufrenite
Epidote
Gold
Heterosite
Kaolinite
Limonite
Melanterite
Molybdite
Malachite
Olivenite
Opal
Pyrolusite
Purpurite
Scheelite
Sericite
Serpentine
Scorodite
Talc
Tellurite
Uraconite
Vivianite

The origin of the tin deposits of the Black Hills was for a long time a disputed question. It was early recognized that in nearly all cases the cassiterite was a true constituent of the rock in which it occurs and hence had an origin practically simultaneous with the associated minerals. The true manner of the formation of the tin-bearing rocks and their relationship was a much debated question due to their relationship to the surrounding rocks, the large size of their component minerals, the gradation into quartz veins and other puzzling characteristics. This condition was also true of similar rocks elsewhere. In late years, however, due to the work of such men as Vogt, Kemp, Bastin, Pirrson, Lindgren, and others the true nature of such rocks has been explained satisfactorily. Without going into detail as to the past theories held with regard to the origin of these tin bearing rocks (practically the Harney Peak granite), we may say that there were proposed two antagonistic theories. One assumes that these rocks are true igneous in origin and were formed by so-called "dry" fusion, hence are supposedly in every way analogous to granites or porphyries. The other view postulates that they are "veins of segregation," i. e., mineral veins formed by meteoric water circulating through the rocks, dissolving out soluble constituents, and redepositing them in favorable places. For a discussion of the former view the reader is referred to the paper given in the bibliography under W. P. Blake's name, while the latter view is best set forth by W. O. Crosby and F. R. Carpenter.

If we, however, apply the results of the researches of the men above mentioned we cannot well hold either one of these theories. All characteristics of the Harney Peak granite seem to show that it represents the upper portion only of a huge granitic mass which has consolidated probably a great distance under the surface. Such a molten mass before solidification is called a magma. The elements which are the most important constituents of such magmas are in order, silicon, aluminum, sodium, potassium, iron, magnesium, and calcium. Such substances as boron, chlorine, fluorine, water, phosphorous, sulphur, titanium, beryllium, lithium, arsenic, are a common characteristic of granitic magmas in small amounts and are held in solution by the great pressure exerted by the overlying rocks. The Harney Peak magma was further characterized by the presence of such rare elements as tin, tungsten, niobium, tantalum, uranium, and even gold, bismuth, and tellurium. All these substances of lesser importance are of great value in these magmas because they reduce the viscosity of the fused mass, and hence permit and aid crystallization. In fact, as has been shown separately, it is impossible to crystallize in artificial fusions, such minerals as quartz and the feldspars unless a certain amount of these substances is introduced to make the fusion liquid. Since these substances aid in the formation of minerals they are frequently called "mineralizers." The presence of mineralizers is considered necessary for the crystallization of such a rock as granite. If we, however, observe a typical granite or rhyolite we find in it no evidence of the presence of such substances as water, chlorine, boron, fluorine, phosphorous, etc. What has become of the mineralizers? The conclusion is that they have been expelled during the process of crystallization just as the cider is expelled during the freezing of the water with which it is mixed. All the substances acting as mineralizers are volatile and under the conditions the most easily fusible. In fact, they form the solution from which the quartz, the feldspars, the micas, and the hornblende crystallize. None of these minerals contain any water, boron, fluorine, etc., hence the remaining solution is continually being enriched in these volatile and fluid components and becomes gradually more and more liquid and mobile. This solution is then expelled and forced out by the crystallizing minerals and travels towards the marginal portion of the magma. Here the rock becomes enriched in minerals carrying these rare elements and if suitable channels are opened they may circulate into the country rock and form vein-like deposits or dikes, or they may act bodily upon the country rock and effect and change it more or less profoundly by formation of new minerals and by recrystallization, thus giving rise to so-called "contact metamorphic" effects. The main mass of the magma in cooling will shrink, and the cracks and fissures thus formed are other channels for the escape of these fluid solutions and vapors, which frequently crystallize in these fissures filling them more or less completely. These solutions may be gaseous or they may be liquid depending on their temperature and the pressure to which they are subjected. The substances crystallize from them in the order of their solubility and since the solutions are far more liquid than the original magma was, the component minerals can grow to large size. Many of the rarer elements are included in these so-called "pegmatites," which are hence spoken of as the home of the rare minerals. Pegmatites then represent a transition from a fusion to a solution as ordinarily thought of. Thus we can find a perfect gradation from the true typical granite into the coarse grained pegmatite, and from the latter, into the ideal true quartz vein, which is the last stage in the whole series and represents the residue highest in water content, from which most of the rarer substance have been removed in the crystallization of the pegmatites.

The Harney Peak granite varies exceedingly in physical and mineralogical characteristics. Usually it is a coarse grained rock whose individual crystals show great irregularity in size and in relative abundance, and whose essential minerals are quartz, albite, oligoclase, orthoclase, microline and muscovite, accompanied by much or little tourmaline, apatite, lepidolite, cassiterite and rarer minerals.

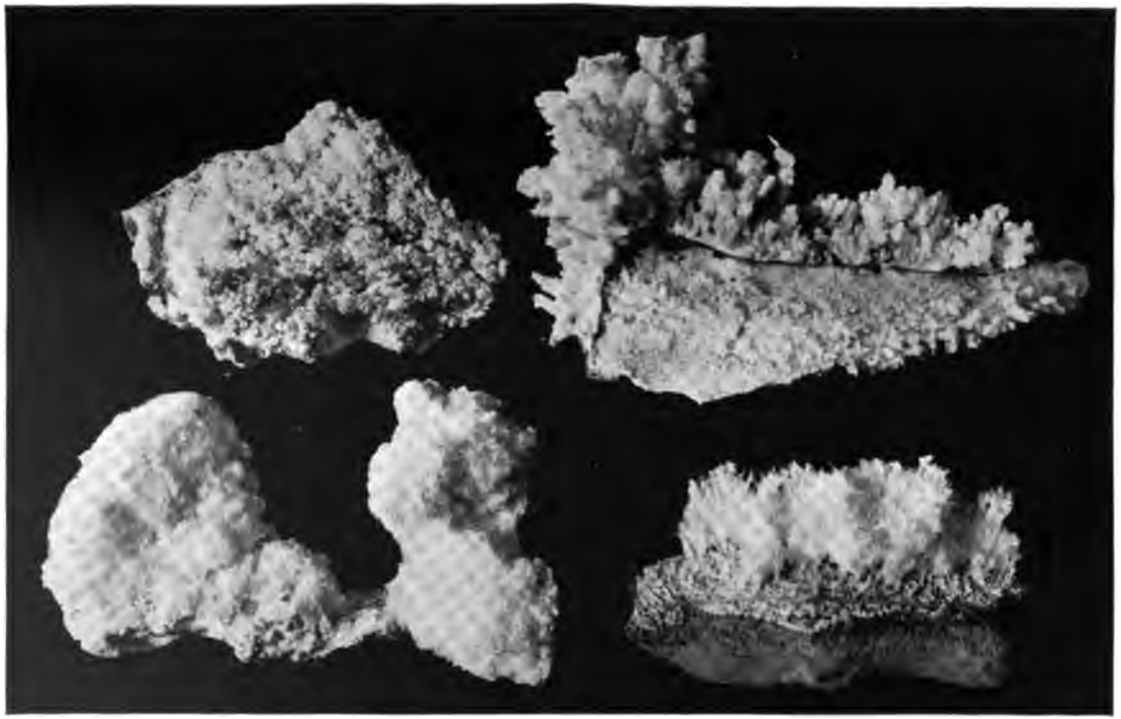

PLATE XII: Aragonite, Wind Cave.
(⅓ natural size.)

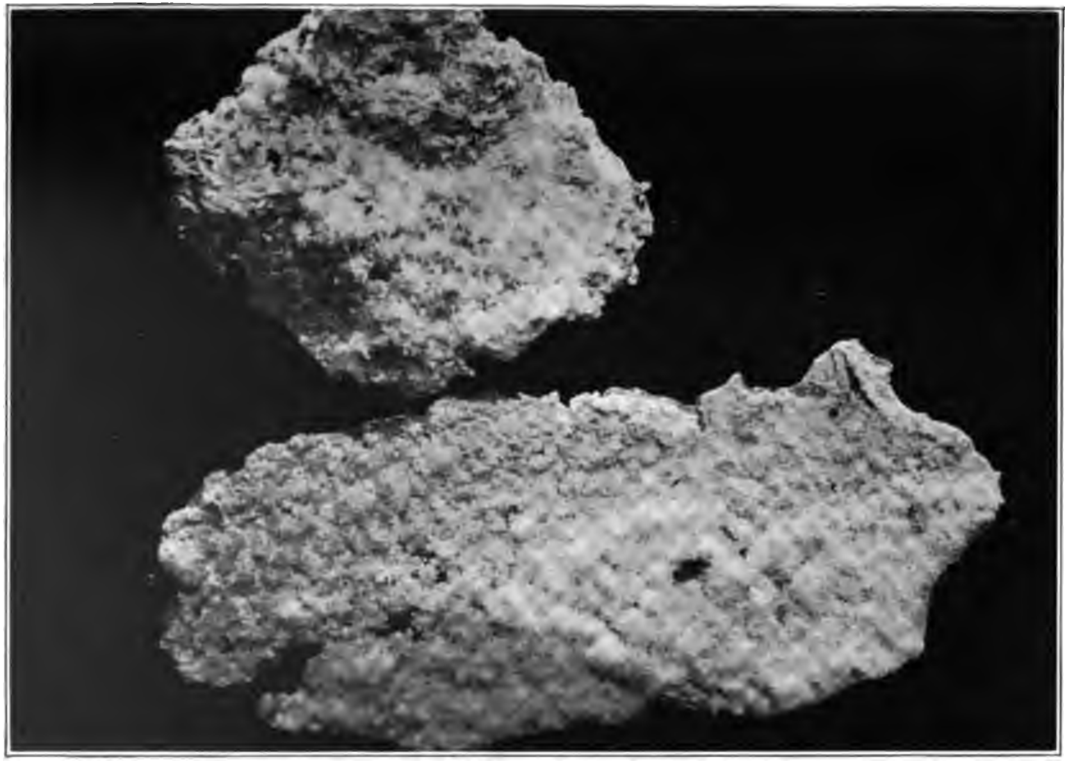

PLATE XIII: Aragonite Frostwork,
Wind Cave. (⅓ natural size.)

Frequently gradations are shown towards a more typical muscovite granite whose essential feldspar is albite, and in other cases perfect gradations towards enclosed pockets or dikes of pegmatite. All these characteristics and the preponderance of minerals carrying fluorine, chlorine, boron, and lithium are the criterion which prove that these exposures represent the marginal phase only of a huge granitic mass.

Frequently the granite or the surrounding country rock is cut by sharply differentiated pegmatites or by quartz veins which represent later phases in the crystallization of the same magma as above described.

In conclusion we may say that cassiterite occurs as a primary constituent in albitic muscovite granites, in pegmatites, and in quartz veins; as a secondary mineral in deposits in place, and as stream tin in placers; and lastly in small amounts as an accessory in rocks that have been affected by contact metamorphism, in which case it has been brought in by the hot solutions coming from the intrusive igneous rock.

62. RUTILE (TiO) (TiO_3).

Rutile occurs in several of the igneous rocks of the Black Hills as a microscopic accessory mineral and in no case known is it apparent to the unaided eye. On Box Elder Creek we find beautiful sagenitic amethyst crystals which are pierced in all directions by fine hair-like needles of rutile. (See under quartz.) Headden (26) describes the only occurrence of rutile in the Black Hills where specimens of this mineral may be obtained. The following description is a condensation of his article.

The specimen was from the Harney Peak district (?) and showed aggregates of small deep black crystals associated with and usually surrounded by muscovite in a mass of feldspar. The crystals have a brilliant metalic luster, a hardness of six, and a specific gravity of 5.294 (?). The streak is grayish black.

The following analyses are also by Headden:

TiO_2	90.78	90.80
FeO	8.10	7.92
SnO_2	1.32	1.38
MnO	trace	trace
	100.20	100.10

Professor Pirrson identified the following crystal forms:

Prisms 1a :αa :1c (1, 0, 1) and 1a :αa :αc

Pyramid 1a :1a :1c (1, 1,).

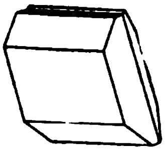

Fig. 47.

Due to the fact that the mineral is elongated along one pair of pyramid faces and the absence of the other two, the crystals appear to be orthorhombic instead of tetragonal.

The specific gravity of the rutile (?) is too high and lately Hess and Wells (104) have challenged the above determination, claiming that the mineral described by Headden is struverite.

63. TAPIOLITE $Fe(TaO_3)_2$.

This mineral occurs rarely associated with cassiterite. Thus Headden describes specimens occurring in granite near Custer. No other specimens are available to the writer and hence the following description is mainly condensed from Headden's (86).

Tapiolite is an iron gray to black mineral appearing much like tantalite from which it only differs in crystal form. The group of crystals found by Headden consisted of highly distorted and striated individuals which were described by Professor Penfield, who identified the two pyramids (1a :1a :1c) (1, 1, 1) and (1a :αa :2c) (2, 0, 1). The former faces are deeply striated and the faces of both forms are curved and uneven. The crystals are "complicated by what is apparently irregular intergrowth and there is also an indication of twinning."

The following analyses are by Headden:

Cassiterite	.31	insol.	1.29
SnO_2	.07		.59
WO_3	.11		
TiO_2	trace		...
Cb_2O_5	4.29		3.90
Ta_2O_5	78.61		78.58
FeO	16.85		15.60
	100.24		99.96

The specific gravity was determined to be 7.2185.

Headden also mentions the probability of the occurrence of tapiolite at Grizzly Bear Gulch.

64. STRUVERITE $FeO (TaCb)_2O_5 6TiO_2$.

This mineral was first described by Hess and Wells (104) in 1911 in the Etta mine near Keystone. The following description in the main is a summary of their description.

The struverite occurred in comparatively fine grained little aggregates which have a metallic luster and a black color. In color and luster it is indistinguishable from columbite according to Hess. Its crystal form was less distinct, but most of the crystals were cruhed. The largest crystals collected were about 5 millimeter by 2 millimeter. The powder and streak are nearly black with a greenish tinge. The hardness is 6-6.5 and the specific gravity 5.25.

Struverite also occurs in the Peerless mine, where it seems to favor the beryl in association. It is quite different in appearance from the columbite being lighter and more bluish gray in color and having a more brilliant metallic luster. The hardness was 6.5 and the specific gravity 5.3.

Mr. Waldemar Schaller to whom crystals were submitted for identification by Hess and Wells identified the following forms:

The crystals are tetragonal, twinned, and distorted, the prism 1a:∞a:∞c (1, 0, 0) and 1a:αa:1c (1, 0, 1) and the pyramid 1a:1a:1c (1, 1, 1) are usually present. The pyramid 1a:∞a:1c (1, 0, 1) is also often present truncating the edges of the other pyramid.

Very careful analyses gave Hess and Wells the following results:

Water	.40	.....
SiO_2	2.00	.....
TiO_2	47.80	49.10
SnO_2	1.30	1.30
FeO	7.30	7.50
Ta_2O_5	34.80	35.70
Cb_2O_5	6.20	6.40
	99.80	100.00

On the basis of this analysis the composition is apparently $FeO(CbTa)_2O_5.6TiO_2$. Schaller (106) challenges the existence of such a compound and believes it to be an isomorphous mixture as follows:

25 parts (8.4%) ferrous columbate
81 parts (41.4%) ferrous tantalate
306.5 parts (48.8%) titanyl titanate
4.5 parts (1.4%) stannyl stannate

This seems the more probable explanation.

Schaller and Hess and Wells believe, as has been suggested under the discussion of rutile, that the mineral thus described by Headden and Pirrson is probably struverite. Due to the difficulties of analyses and the very unsatisfactory methods it is entirely probable that both niobium and tantalum were weighed up and determined as titanium.

So far specimens of struverite are only known from the Etta and the Peerless and appear more plentiful in the former.

Hess and Wells conclude that "although it occurs in considerable quantity, the mineral gives little promise of having commercial value as an ore of tantalum, owing to the high titanium content."

65. PLATTNERITE PbO_2.

Occurs in minute crystals with a sub-metallic bright luster, suggesting by its prismatic shape stibnite. It differs from this in color, being almost black. Has no cleavage. The crystals are tetragonal, usually a simple prism 1a :1a : ∞c (1, 1, 0) modified by the pyramid (1a :1a :1c) (1, 1, 1) or by a basal pinacoid, (∞a : ∞a :1c) or by both. At Carbonate it is very rare in small rusty masses of black color. The streak is reddish brown, the hardness is about 5, and the cific gravity 8:42. It is a very rare mineral occurring above the ground water level in the mines of the Carbonate and Galena districts. It was first identified in the Black Hills by Fowler (74).

It is usually associated with cerussite, cerargyrite, anglesite, wulfenite, vanadinite, pyromorphite, matlockite, calcite and limonite, and is an alteration product of galena.

66. PYROLUSITE MnO_2.

This mineral is quite widely distributed throughout the Black Hills in minute amounts. It is always iron black in color, has a decided metallic luster if crystalline or if not, a dull luster, and a black streak. It is very soft and comes off on the hands. Occurrences in the Hills are as follows:

1. In Algonkian rocks in Custer and Pennington counties.
2. In fissures and beds in Carboniferous limestone near Custer.
3. In pockets, layers and fissures in the Minnelusa sandstone near Argyle.
4. As dendrites.
5. In quartz veins in the Bear Lodge Mountains.
6. Hair-like in fossils of the Bad Lands.

In occurrence 1, 2, 3 and 5, pyrolusite is only a very minor constituent, accompanying wad which is also associated with manganite in small amounts.

The mixture of manganese oxide in the Carboniferous limestones near Custer occurs as nodules, layers and pockets in caves often mixed with crystalline calcite. Analyses gave the following:

Mn	46.05
Fe	3.93
P	.05
SiO_2	8.00
Moisture	4.70

Analyses made at the State School of Mines by Prof. Coolbaugh showed 46.4, 33.63, and 28.04% of manganese.

The deposits in the Minnelusa sandstone occurring in disseminations and layers and also irregular bunches near Argyle are the most extensive deposits (65).

In the Northern Black Hills, wherever the rhyolites and the quartz porphyries outcrop, we are liable to find pyrolusite occurring as dendrites. They are usually very delicate fern-like or tree-like series of minute veinlets deposited from solutions circulating through the joint planes to which the dendrites are restricted (See plate). Very striking and beautiful specimens occur thus. Frequently these manganese bearing solutions have circulated over quartz and chalcedony and beautiful so-called moss-agates result.

In the Bear Lodge district well developed quartz veins cutting granitic porphyries are said to carry high amounts of manganese minerals mostly pyrolusite and manganite associated with wad.

Many of the fossils occurring in the White River Bad Lands are coated along minute cracks with dendrites of manganese dioxide. Cavities, especially in titanothere teeth are frequently filled with a hair-like reticulated net-work of pyrolusite fibers. These are deep bluish black in color and have a bright metallic luster.

No manganese is being mined within the Black Hills region at this time. A small shipment (19 tons) was sent out about 1899, but nothing has been done since in the way of production.

67. MANGANITE $MnO.OH$.

As has been indicated under pyrolusite, this mineral is usually an associate. Thus it occurs sparingly, accompanying wad at Custer and elsewhere. It has essentially the characteristic appearance of pyrolusite, i. e., it occurs in prismatic black, metallic crystals. These have a brown streak and are harder than pyrolusite. Upon heating in a closed tube they also yield water. Their specific gravity is about 4.3+, while that of the accompanying pyrolusite is 4.7+. It occurs also associated with pyrolusite in the Bear Lodge Mountains (44).

68. LIMONITE $2Fe_2O_33H_2O$.

This is one of the most common of minerals and may be found practically anywhere. It is a decomposition product of any substance containing iron and is the rusty staining coating many rocks and any iron left exposed to the action of the weather. Sulphides of iron, such as pyrite, pyrrhotite, and arsenopyrite, are readily oxidized to limonite, hence we find the upper portions of pyrite-quartz veins and of large pyrite bodies, frequently completely changed into limonite as far down as the ground water level. Such a capping we call an "iron hat" or a "gossan."

Frequently the pyrite is converted into this iron oxide without losing its crystal shape, thus forming a pseudomorph. Such cubes and octahedrons of limonite occur in the upper part of many of the quartz veins, but are best shown near the western border of the Algonkian area on Rapid Creek, where they occur in a decomposed micaceous slate.

Stalactites and botryoidal structures are common, due to deposition of limonite by water in caves or along fissures. The rounded botryoidal shapes are often erroneously thought to be a result of fusion. In color this type of limonite is black to brown, and frequently has a beautiful play of prismatic colors on the surface, called iridescence. Specimens from Iron Hill near Keystone show iridescence which may be intensified by heating the specimen.

Limonite is a common deposit in swamps and ponds where it forms a yellow to brown somewhat flocculent material which settles in the bottom. A thin coating of limonite on water causes an iridescent play of colors frequently thought to be due to thin films of oil. A little acid added to a few drops of such water will cause a disappearance of the turbidity and color if due to iron, but will have no effect on oil. Limonite deposited in swamps frequently called "bog iron" may be dense, black and metallic, but is usually cellular or earthy, light to dark brown, and friable, in which case it is called yellow ocher and is suitable for natural paint. In many of the creeks west of Rochford, a soft limonite is now being deposited. It forms as a soft brown and fluffy material on mosses and twigs and other rubbish, and quickly hardens after deposition.

One hundred fifty to two hundred tons of such material have been mined in this vicinity and used in the manufacture of paint.

Similar deposits occur near Nahant. The source of this limonite may be found in the pyrite and pyrrhotite, which is fairly plentiful in the slate and schists of this region, and which is readily oxidized when exposed to the action of the atmosphere. (For a discussion of the oxidation of pyrite see the discussion under this mineral.)

The specific gravity of limonite depends on the specimen or variety and runs from 3 up to 4.2. The hardness varies up to 5.5. The streak is always decidedly yellowish brown.

A specimen from a bog iron deposit near Rochford had the following compositions according to an analysis by Professor Coolbaugh:

Fe	53.80%
SiO_2	3.90
Al_2O_3	trace
P	trace
S	0.57
CaO	trace
MnO_2	trace
MgO	trace

Next to hematite it is the most important ore of iron.

For a summary of occurrence in the Black Hills see under hematite, with which it is nearly always associated.

69. WAD.

Wad is an impure mixture of manganese oxides and represents a bog deposit. The major part of the manganese ores mentioned as occurrence 1, 2 and 3 under pyrolusite,, viz. in Algonkian rocks, in limestones near Custer, and in the Minnelusa sandstone near Argyle respectively, is wad.

This varies from brownish black to dull black in color, rubs off readily on the fingers, and gives a brownish colored streak. Usually it is loosely aggregated, often botryoidal or concretionary, varying in hardness up to about 5.5, but is commonly soft. On account of its porous structure it seems very light, although the specific gravity of the picked specimens will run as high as 4.3.

The most extensive deposits occur near Argyle and apparently represent a surface concentration of manganese in a sandstone.

70. CUPROCASSITERITE.

In both the Peerless and the Etta mine, as has been mentioned under stannite, there occurs a green earthy decomposition product very much like malachite or chrysocolla in appearance. It is usually a decided bluish green to grass green color, but grades into a peculiar dirty yellow green, and according to Headden, into brown and even into black.

Ulke (36) first called attention to a green variety of this material and briefly described it as a new mineral giving it the name of cuprocassiterite. An incomplete analysis led him to give the mineral the following composition: $4SnO_2+Cu_2Sn(HO)_6$. The analysis showed:

Sn	62%
Cu	13%
Water	6%
Iron and Silica	trace

The hardness is three; the specific gravity, 5, and the streak white. Headden (32) subsequently discussed the alteration products of stannite and comes to the conclusion that this formula is not accurate, that it varies widely and that "cuprocassiterite" is more probably a mixture of several alteration products. Headden gives the following analyses; II. being from the Peerless and I. from the Etta:

	I.	II.a	II.b	II. corrected to 100
Water	13.87	8.20	9.68	
CuO	12.53	18.02	21.34	
Fe_2O_3	8.94	11.85	13.98	
SnO_2	64.33	46.07	54.40	
SO_3	trace	trace	....	
Sb_2O_5	trace	trace	....	
ZnO	trace	.51	(incl. CbO)	.60
Gangue	....	1.68	}	Insol. in HCl
SnO_2 (Fe trace)		12.96		

Specific gravity 3.312 and 3.374.

These analyses show the wide variation in the composition. Thus analysis I. indicates the composition Fe_2O_3. $2H_2O$, $3Cu(OH)_2$, $5Sn(OH)_4$, $3SnO_2$, while II. indicates

$2Fe_2O_3$, $6CuO$, $7SnO_2$, $11\ H_2O$ (30). Neither gives any simple or even evident formula, as pointed out by Headden.

A very careful perusal of both the discussions by Ulke and by Headden, lead one, however, to the conclusion that both had different material in mind. Undoubtedly the brownish to black material analyzed by Headden is a mixture of the bright green mineral discussed by Ulke with some other decomposition product. This green mineral is abundant in the Etta and Peerless and is usually a malachite green in shade, has an unctuous luster and adheres strongly to the tongue. Repeated qualitative tests failed to show more than a trace of ferric oxide, but shows strong tests for tin and copper and water. It occurs as a coating in the fractures of milky quartz in the pegmatites of the Etta and Peerless claims, as a staining material and coating in the flakes of muscovite, or the cleavage of albite, and also accompanying coarse crystalline iron black cassiterite in the Etta. The green coating may even reach a thickness of one-eighth inch along minute fissures. The author was fortunate enough to secure specimens of stannite, heavily coated with cuprocassiterite at the Etta.

The formula established by Ulke can not be accepted for this mineral since he includes in it a certain amount of tin oxide, which was insoluble in acids and in all probability was present as cassiterite. That such cassiterite is present is easily shown by a microscopic examination. It seems practically certain, however, that this green material is a copper tin hydroxide, for which we may well retain the appropriate name given by Ulke, "Cuprocassiterite." The material analyzed and described by Headden does not appear to be the same material, but a mixture of the cuprocassiterite of Ulke with some other alteration products, probably as Headden intimates, xanthosiderite. Blake (12) mentions a peculiar brown hydrous oxide of tin, which may also be present in the material analyzed by Headden.

GROUP OF OXYGEN SALTS.

a. Carbonates. This group comprises a series of mininerals characterized by lack of hardness and by the fact that they all effervesce when treated with acids.

THE CALCITE GROUP.

The calcite group is in isomorphous group consisting of a series of carbonates of calcium, magnesium, iron, manganese, and zinc. All of these crystallize in the hexagonal system and usually occur in rhombohedrons or scalenohedrons. They all have excellent rhombohedral cleavage.

The following minerals of the calcite group are known from the Black Hills:

Calcite	$CaCO_3$
Magnesite	$MgCO_3$
Siderite	$FeCO_3$
Dolomite	$CaMg\ (CO_3)_2$
Ankerite	$CaMgFe\ (CO_3)_3$
Smithsonite	$ZnCO_3$

All gradations in composition from one member in the group to another occur and, as emphasized before, are a characteristic of isomorphism.

71. CALCITE $CaCO_3$.

This mineral frequently known under the misnomer of lime to the prospector, is of practically universal occurrence and specimens may be obtained anywhere. It is very common in crystals and a great variety of different forms have been identified. More than eight hundred types of crystals are known, including single forms and combinations. In the Black Hills a great variety exist. Many of these cannot be determined without measurement with reflection goniometers, but some forms are readily recognized.

Thus we have seven distinct rhombohedrons, three scalenohedrons, two pyramids, the basal pinacoid and the prism. In addition we have many other forms not yet identified.

Rhombohedrons:

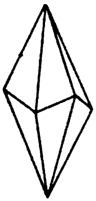

Fig. 48.

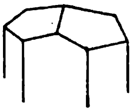

Fig. 49.

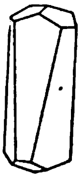

Fig. 50.

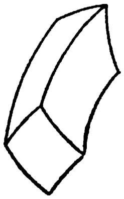

Fig. 51.

1. a :∞a :a :c ....(1, 0, 1, 1)
2. a :∞a : a : ½c..............(1, 0, 1, 2)
3. a :∞a :a : 4 c................(4, 0, 4, 1)
4. a :∞a :a : 16 c.............(16, 0, 16, 1)
5. a :∞a :a : 13 c............(13, 0, 13, 1)
6. ∞a : 1 a : 1 a : 2c...........(0, 2, 2, 1)
7. 1a :∞a : 1a 4c.............(4, 0, 4, 1)

Scalenohedrons:

1. 3a :6a :2a :6c ....(2, 1, 3, 1)
2. 5a :15a :3a :15c ....(3, 1, 5, 1)
3. 4a :12a :3a :2-2-5c ....(3, 1, 4, 5)

Pyramids:

1. 1 a :∞a :1 a :∞c.............(1, 0, 1, 0)
2. 7a :7a :3a :16c ....(8, 8, 16, 3)

Basal Pinacoid:

1. ∞a :∞a :∞a : 1 c.............(0, 0, 0, 1)

Prism:

1. 1 a :∞a :1 a :∞c.............(1, 0, 1, 0)

The various combinations present crystals frequently of much complexity. Specially interesting of many are the combinations and developments shown above. Photographs of crystals are shown on plate VII.

Calcite from the Homestake mine, occurring as an incrustation on slate gave Sharwood (103) the following result on analysis:

	I.	II. Crystals.
Insoluble	1.34%	....
Sulphuric acid	trace	....
Water	1.30%	....
Calculated to 100%:		
$CaCO_3$	99.45%	99.4%
$FeCO_3$	.55%	....
$MgCO_3$	trace	.6%

Another specimen probably referrable to Calcite, creamy in color and containing 6.2% impurities had the following composition:

$CaCO_3$	87.50%
$MgCO_3$	7.05
$FeCO_3$	5.68

Which would approximate a compound containing 20 parts $CaCO_3$, 2 parts $MgCO_3$, and 1 part $FeCO_3$.

Calcite has excellent cleavage parallel to the rhombohedron (1). Crystalline clear fragments possess the property of breaking up a ray of light into two rays (i. e., double refraction) to a marked degree and hence if we place such a cleavage fragment upon a mark we will see a double image. The hardness is three, hence it is very readily scratched by a knife. Its specific gravity is 2.72—about the same in weight as an average rock.

Calcite occurs in a great number of varieties, chief of which are the following:

A. Crystalline.

1. Dogtooth spar—consists of well crystallized calcite in the form of the scalenohedron (1) usually. This terminates in exceedingly sharp points suggesting the teeth of a dog. This type may be found in vugs in many of the limestones, but especially the Pahasapa. They are well developed in Jewel cave near Custer and are here usually associated with siderite.

2. Nailhead spar—short, stocky crystals formed by the combination of several rhombohedrons, giving rise to a rounded flat form. These are prominent in Jewel cave, where they are very clear to milky, and have a bright luster, and are frequently striated. Such forms also occur in the Bad Lands.

3. Satin spar—calcite showing a delicate silky to velvety luster occurs in Wind cave at Hot Springs, usually associated with aragonite. The common form is a scalenohedron modified by a rhombohedron.

4. Prismatic calcite. Long apparent prismatic forms made up of an acute rhombohedron ((4) or (5)) in combination with a second flat one (2) occur in the Homestake mine, in Jewel and Wind caves, and in the Bad Lands.

5. Golden Calcite. Beautiful golden yellow to orange yellow crystals of calcite occur in the concretions in the Pierre shale, especially in the Cheyenne river country. These were first described by Farrington (53a). They are unusual on account of their distortion. The common form is a rhombohedron (6) elongated parallel to a rhombohedron face so that it suggests an elongated monoclinic prism. In others the crystal is distorted in two directions, resembling a very flat tabular monoclinic prism. In either case both the terminal and the elongated faces are curved as though a torsional pull had elongated the crystal and had twisted it on it long axis. (Fig. 51.)

6. Sand Crystals. These crystals, also known under the less appropriate name of Fountainebleau sandstone, due to their occurrence near Fountainebleau, France, were first described from the Bad Lands by Barbour. They consist of crystals of calcite which have formed in loose sand and during the process of crystallization have enclosed as much as sixty or more per cent of the loose sand grains, so that at first sight they appear to be crystals of sand. These crystals vary from minute size up to 15 inches or more in length. The crystals occur as single individuals or as regular and complex aggregates and show all gradations to rounded bunches, radiating concretions and irregular masses of solid rock. Barbour (6) well described their occurrence at Devils Hill, Washington County, as follows: "The mode of occurrence of these crystals seems most unusual and remarkable. In a bed of sand scarcely three feet thick, and so soft as to resemble the sand on the seashore, occur these crystals in numbers which can best be figured in tons. We dug them out with our bare hands. They are mostly single crystals, with numerous doublets, triplets, quadruplets and multiplets. In other words, every form from solitary crystals to crowded bunches and perfect radiating concretions were obtained. It was a matter of special interest in the field to note that at the bottom of the layer the bulk of these sand-lime crystals are solitary; one foot higher there is an evident doubling of the crystals, until within another foot

they are in loosely crowded clusters; a little higher in closely crowded continuous clusters, pried out in blocks with difficulty; still higher they occur in closely crowded concretions in contact with one another, making nearly a solid rock. A little higher this mineralizing process culminates in pipes, compound pipes, and solid rocks, composed wholly of crystals, but so solidified that their identity is lost, and is detected only by a certain reflection of light, which differentiates the otherwise invisible units by showing glistening hexagonal sections. There could not have been a more gradual and beautiful transition, and all confined to a bed six or eight feet in thickness."

Among the forms represented on these crystals the following have been identified: Scalenohedrons modified by a rhombohedron; a hexagonal pyramid modified by rhombohedron; a very acute rhombohedron modified by an obtuse rhombohedron. The latter are from the Goshen Hole Region, Wyoming (63).

The following analyses will show the presence of the large amount of sand:

III.	% of sand.	%. of Soluble matter.
Crystals—Devils Hill	63.81	36.19
Concretion—Devils Hill	61.88	38.12
Sand crystal rock—Devils Hill	63.43	36.57
Radiate concretions, Sioux County, Neb.	58.89	41.11
Crystals, Goshen Hole, Wyo.	63.63	36.37
Concretions, Golden Hole, Wyo.	62.54	37.46

Complete analysis of the Goshen Hole material gave Warner (cited by Barbour) the following result:

	Crystals.	Concretions.
SiO_2	49.32	47.94
P	0.011	0.01
Fe_2O_3	14.21	14.52
$CaCO_3$	33.27	34.24
$MgCO_3$	3.14	3.25
Undetrmined, probably Mn	0.049	0.04

The following paragraph regarding the distribution of sand crystals is quoted from Barbour and Fisher (64):

"The distribution of sand crystals is very wide, though they are little known and seldom recognized from the fact that the more obscure forms pass for concretionary sand and receive no attention. They have been personally observed at and around Devil Hill, in the Indian Reservation of South Dakota; in Sioux County, Nebraska; in the North Platte region in Nebraska; at Goshen Hole, Bates Hole, and intermediate points in Wyoming.

The larger crystals present no such disparity between the component sand and gravel grains and the crystal itself as do the lesser ones, hence their forms are defined and perfectly apparent. Such forms are restricted and very local in area. Those at Devil Hill occur in enormous quantities along about 100 yards of exposure. The total extent of the bed, which is but a mere remnant of the original, is scarcely one acre. Those from the region of the North Platte river, at or near the Nebraska line, seem to be even more local, and are very scattered in number. The same seems to hold true of those in the Goshen Hole country, which may be classed with the North Platte region, both producing the same crystalline forms, though differing in horizon. There are but the three above named localities known in this country which produce these crystals. In France, at Fontainbleau, the crystals are similar in physical properties to those from the Great Plains, though differing crystallographically, inasmuch as they are simple unmodified rhombohedrons.

In vertical range these forms occur in greatest numbers in the Arikaree, though found as low as the Chadron sands at the base of the Oligocene. In the basal sands of the Laramie of Wyoming occur numerous examples of the obscure or concretionary type."

Tertiary	Miocene (Arikaree)	Devil Hill, S. D. Sioux County, Nebr. Goshen Hole, Wyo. Bates Hole, Wyo.
Cretaceous	Oligocene (Chadron Sand) Laramie	Mitchell Region, Neb. South of Buffalo, Wyo. Obscure crystals or concretionary sand.

B. Massive Varieties of Calcite.

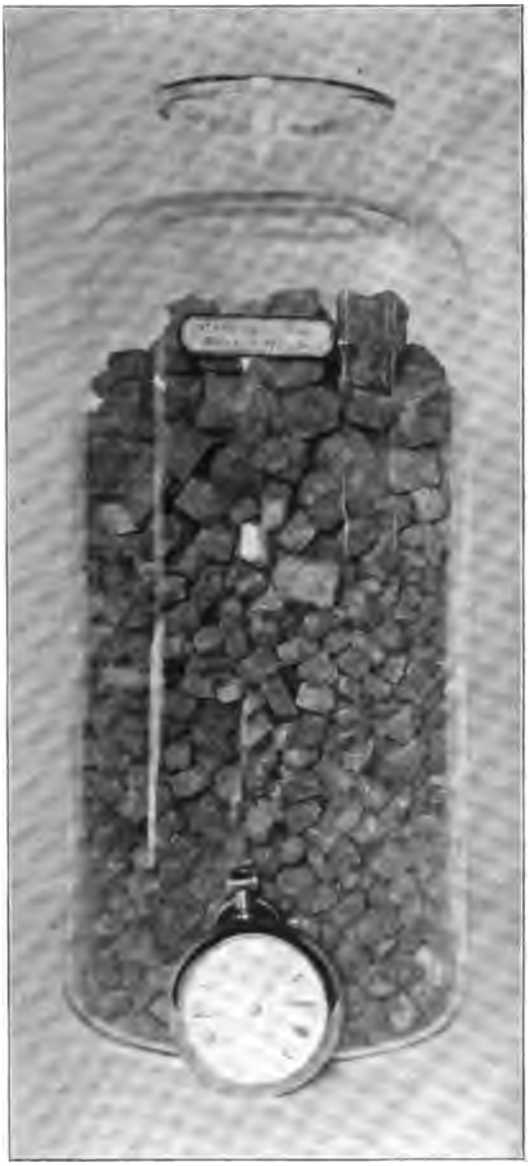

PLATE XIV: Orthoclase Crystals.
Black Buttes, Wyo.

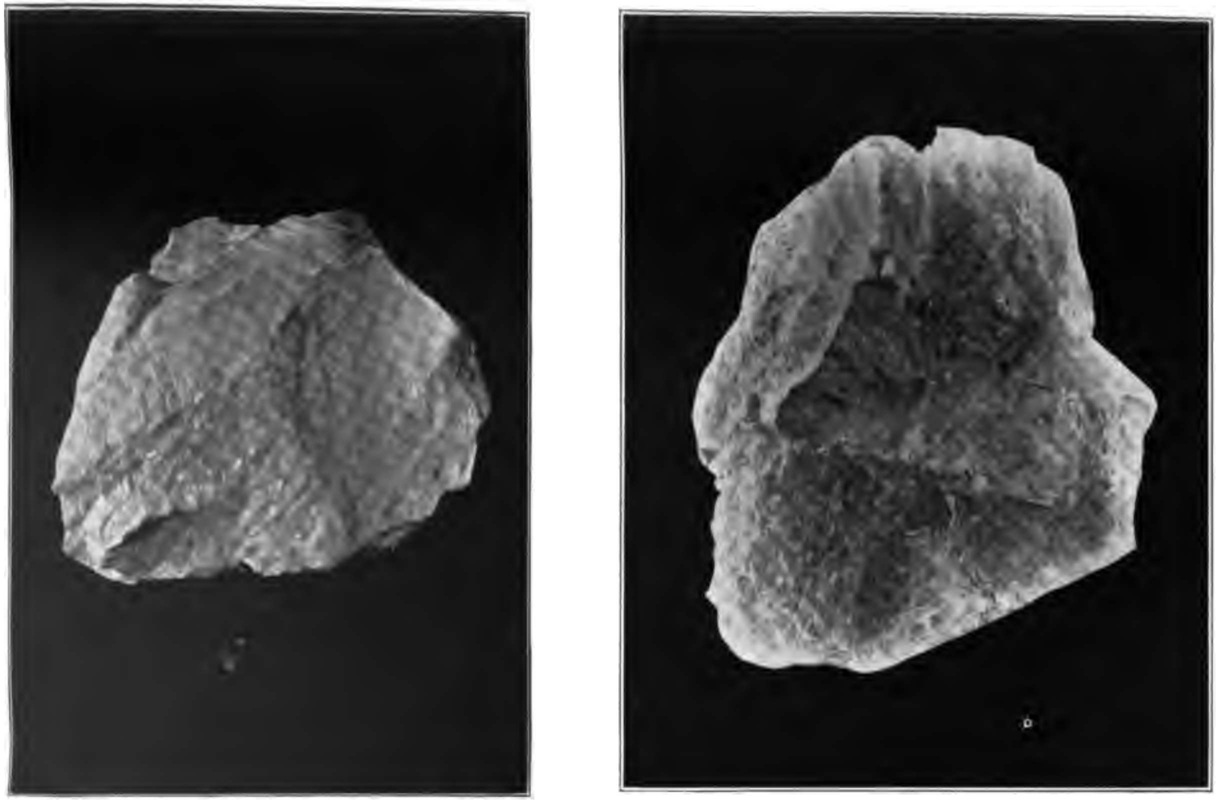

PLATE XVI:

Cymatolite,
Harney Peak.
(⅔ natural size.)

Andalusite,
Oreville.
(¼ natural size.)

1. Stalactites and stalagmites. These can be found in many of the numerous caves of the Black Hills, often attaining large size. Such occur in Wind Cave, near Hot Springs, in Jewel cave, near Custer, in Crystal cave, near Piedmont, and in other less noticeable ones. These are usually made up of fibrous to columnar calcite laid down in parallel layers and varying in color from white and gray into yellow and brown. Often beautiful banding and sharp contrasts are shown in specimens after polishing. To such the name Mexican onyx is applied.

2. Saccharoidal limestone. Eight to ten miles northwest of Custer, there occurs a beautiful colorless dolomitic limestone made up of small crystalline grains of lime and magnesia carbonate which closely resembles a mass of sugar. This material is not very compact and hence not suitable for polishing.

3. Limestone. These rocks are made up of calcite. When they are rich in magnesia the limestones are spoken of as dolomitic. Such minerals as quartz, kaolinite (china clay) and other clays, limonite, and hematite, and organic material are frequent impurities. Limestones vary in color from grayish into drab, yellowish, or reddish and even purple. They are formed from the accumulated remains of lime-secreting animals such as corals, crinoids (stone lilies), molluscs, and braechiopods (lamp shells), and frequently show remains of the hard shells of these animals as fossils. The Pahasapa formation in places is crowded with bracchiopod shells as are some of the other less important limestones. Occasionally the Pahasapa grades into a very compact fine grained rock of grayish buff color when it becomes suitable for stone engraving and hence is called lithographic limestones. Chalk, a variety dull white to gray in appearance and color and usually quite friable, occurs (very impure, however) in the Niobrara formation. It is formed by the accumulated shells of very minute, even microscopic animals. called foraminifera.

The Minnekahta formation is the purest of the limestones of the Black Hills, and is used to a considerable extent in the manufacture of lime.

As the amount of impurities in the limestones increase it is indicated by the name. Thus ferruginous limestones are high in iron oxides, argicillaceous are high in clay, siliceous are high in quartz. The Greenhorn formation is a good example of an argillaceous limestone, while the Pierre shales are an example of calcareous shale, i. e., one carrying lime carbonate.

In some impure limestones and sometimes in calcareous shales, we find a curious structure, which appears to consist of series of interlocking cones usually arranged in sets which have their long axes parallel.

On fractured surfaces such a rock seems to consist of a number of cones set into each other. Hence the name "cone in cone" is applied to it. This structure is apparently due to concretionary action, by which the carbonate of lime is recrystallized, partially expelling the clayey material. Various stages in the development of such structure are shown on Plate IX.

4. Marble. When limestones are subjected to pressure or heat they tend to recrystallize and during this process the minute crystals of the calcium carbonate tend to grow to a larger size. A limestone that has been thus changed or metamorphosed becomes a marble. These occur in small amounts near Custer, usually carrying serpentine, actinolite and phlogopite. The serpentine causes a yellowish or greenish mottling which gives the marble a handsome appearance after polishing. In the vicinity of Black Buttes, some marble occurs. This is grayish white in color, mottled with yellow due to limonite, and is capable of taking a high polish.

72. MAGNESITE ($MgCO_3$)

This mineral has been reported at various times as occurring in the Black Hills, but nothing definite is known regarding it. (100)

73. DOLOMITE $CaMg(CO_3)_2$

This carbonate of calcium and magnesium is of rare occurrence in the Hills, but may be found as minute rhombohedrons with curved faces lining druses in some dolomitic limestone. They have been thus observed, but no specimens are available for description.

Irving (73) describes pseudomorphs of quartz after dolomite formed during the silicification of sandy dolomite which now form part of the siliceous or refractory gold ores of the northern Black Hills. Vugs in these ores are occasionally lined with well-defined curved rhombohedrons of quartz, but as a rule these pseudomorphs are only visible in thin sections under the miscoscope.

74. ANKERITE (CaMgFe)CO_3.

This carbonate is a frequent gangue mineral in veins and ore deposits. Sharwood reports carbonates probably corresponding to this from the Homestake, and gives the analyses quoted below. Number 1 is a black opaque material occurring in patches between other minerals, and is quite rich in graphite. It was quite impure, carrying 63.44% insoluble matter. Number II is a nearly pure white carbonate which occurs in small masses showing repeated twinning.

		I. Calculated to 100	II. Calculated to 100
Soluble 36.50			
$CaCO_3$	19.21	53.05	49.12
$MgCO_3$	14.52	40.10	18.08
$FeCO_3$	2.48	6.85	32.47
$MnCO_3$	trace		0.11
$SiO_2Al_2O_3$	0.35		
Insoluble 63.68			30.00
FeS_2	5.37		
SiO_2	37.86		
Al_2O_3	6.50		
Fe_2O_3	0.35		
CaO	0.10		
MgO	trace		
Loss on ignition	9.96		
Undetermined*	3.30		

*Alkalis, TiO_2, MnO_2 graphite.

This gives the following ratios:

	I.	II.
$CaCO_3$	9	7
$MgCO_3$	8	3
$FeCO_3$	1	4

Analysis I very closely approximates dolomite in composition, while II is a more typical ankerite.

75. SIDERITE $FeCO_3$.

This mineral is very common as a gangue mineral. It occurs as a primary constituent in some of the cassiterite and wolframite veins of the southern Black Hills and is listed in the mineral table given in the discussion under cassiterite. In this case it is formed by the hot solutions arising in the expiring stages of igneous activity which formed the granite of the Harney Peak district. In the vicinity of Mystic and Rochford, siderite occurs in quartz veins in intimate intergrowth with biottie. It occurs in excellent cleavable masses of fairly deep chocolate brown color, traversed by thin flakes of biotite up to an inch and a half in diameter. The siderite is very soft (3), readily scratched by a knife and is 3.78 in specific gravity.

In Jewel cave siderite occurs associated with aragonite and calcite. It usually occurs as a core of yellowish brown cleavable masses in stalactites of calcite and even as a core in the center of scalenohedral crystals. In the latter case the crystals of siderite and of calcite have the same orientation and cleavages pass directly through both. The cleavage plane in the calcite is a nearly perfect plane, in the siderite it shows a slight curvature. A thin, pale brown, almost amber colored layer marks a transition from the siderite into the calcite. Siderite also occurs in coarsely cleavable masses of deep brown color as a cementing material of brecciated limestone probably formed by collapses of the roof in Jewel Cave.

Calcite crystals from the Bad Lands occurring in a slightly brecciated shale are often associated with siderite. Such a specimen in the State School of Mines collection shows a nucleus of shale surrounded by a thin band of fibrous chestnut brown siderite about ⅛ inch in thickness. This is covered by a layer of milky fibrous aragonite of about the same thickness, succeeded by 2-3 of an inch of pale amber colored aragonite, which in turn gives way to clear yellowish white nailhead spar.

Small amounts of siderite occur in many of the mines. Sharwood (103) gives the following analyses of siderite from the Homestake mine:

	I.	II.
$CaCO_3$	0.00*	1.19*
$MgCO_3$	22.5*	6.93*
$FeCO_3$	77.5*	90.30*
$MnCO_3$	trace*	1.67*
Impurity	8.6	0.64

This yields compounds of the following ratios:

	I.	II.
$CaCO_3$	0	1
$MgCO_3$	2	8
$FeCO_3$	5	80
$MnCO_3$	0	1

Both approximate siderite more closely in composition than any other member of the isomorphic series.

76. SMITHSONITE $ZnCO_3$.

The zinc carbonate is only known so far from the Tiger Mine near Hayward, where it is associated with Calamine. Here it occurs as a decomposition product of sphalerite, but is much rarer than calamine. In appearance, color and hardness, it is very similar to the latter mineral, but may be distinguished by its vigorous effervescence when heated with acids. By means of a cadmium borotungstate solution the author was enabled to separate crushed fragments of the aggregate of the two minerals. With the solution at Sp. Gr. 3.5 the calamine floated while the smithsonite settled out. Its specific gravity was subsequently determined to be 4.421, fully 30% heavier than the calamine.

THE ARAGONITE GROUP.

Under this group we include carbonates of calcium, lead, barium, and strontium, all of which crystallize in the orthorhombic system.

77. ARAGONITE $CaCO_3$.

Calcium carbonate is a dimorphic substance—one that occurs in two forms. Under calcite we found this substance described when it crystallizes in the hexagonal system. Occasionally we find $CaCO_3$ in forms belonging to a system of far lower symmetry—the orthorhombic—when the name aragonite is applied to it. In keeping with difference in the form or crystal, there is also a marked difference in characteristics. The conduction of heat and the transmission of light differ decidedly. Calcite has a specific gravity of 2.72, aragonite of 2.93. Calcite is three in hardness, aragonite is 3½ to 4. Calcite is stable under ordinary atmospheric conditions, aragonite is not and readily changes in characteristics over to calcite. This is also the reason why we find limestones made up of calcite rather than aragonite. These puzzling differences are accounted for by different conditions of temperature, pressure, or character of solution at the time of crystallization. Aragonite is frequently spoken of as Flos Ferri—signifying flower of iron, because as delicate moss-like efflorescences it occurs in some iron ore deposits.

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*Calculated to 100%.

In the Black Hills aragonite occurs as a gangue mineral in certain of the mines, as for example the Homestake, the Golden Reward, and other mines in the Ruby basin, and the Standby near Rochford. In the vicinity of Silver City, Mystic, Rochford and elsewhere in the central Black Hills, this mineral occurs in small radiating crystalline aggregates along cracks and fissures in quartzites, slates, and some amphibolites. The individual crystals, while small are well defined and show the simple prism (a:b:αc) (1, 1, 0). The terminal faces are usually destroyed, but the pinacoid αa:αb:c (0, 0, 1) is present in some. These minute crystals are never more than one-tenth of an inch in thickness and 1 inch in length. They show cleavage parallel to the prism faces, and well defined cleavage or parting parallel to the basal pinacoid which is quite unusual for this mineral. In specimens of exquisite beauty it is found as a lining in many of the caves. Wind cave near Hot Springs stands practically unrivalled in the beauty and splendor of its decorations of snow white aragonite.

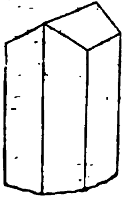

Fig. 52. Aragonite.

It is indeed difficult to imagine anything more striking than winding caves and passages with snow-white aragonite and calcite crystals covering the walls, and stalactites and stalagmites on roof and floor, suggesting here a bride draped in a snowy veil, there the rolling top of a glistening glacier, or a grotto of thousands of ice columns, a veritable fairies palace. No one can do justice to the beauty of nature's handiwork as exemplified in this one lavish display. The following description can do no more than give a poor idea of the real beauty of this mineral.

As a rule the aragonite is associated with calcite often quite intimately. The calcite tends to crystallize in scalenohedrons which have already been described. The aragonite varies decidedly in shape. One common form consists of aragonite covered with minute silky scalenohedrons of calcite arranged in a series of intersecting planes, suggesting the pigeon holes in a filing cabinet. To this variety the term "box work" is given. This has evidently resulted from the circulation of lime-bearing waters through fissures and cracks in the rocks and the subsequent removal of the interstitial material. Frequently the box work is covered with botryoidal masses of aragonite made up of small hemispherical masses. Popularly this is called popcorn aragonite. At other times the aragonite becomes fibrous, often hair-like, and takes on forms which are exceedingly delicate. To these the name frostwork is given. In a protected niche in one of the chambers of Wind Cave may be found one of the finest growths of frostwork imaginable. This consists of exceedingly delicate hair-like fibers two or three inches through and 15 to 16 inches long, suggesting a white flowing beard, and hence known as Noah's beard. The fibers often radiate out from a center and when they are densely aggregated or sperical appear like a snowball. At times the aragonite is stained yellowish, brown or pink, due to the presence of small amounts of iron. The stalactites and stalagmites appear to be more often calcite than aragonite, although frequently fibrous bands of aragonite are present as interbedded layers, showing that there had been changes in the character of the solutions from which these minerals crystallized.

Many of the minute fibers of aragonite have crystal outlines. These show an orthorhombic prism (1 a : 1 b : α c) (1, 1, 0), modified by pinacoids (α a : 1 b : α c) (0, 1, 0), and by domes (α a : 1 b : 1 c) (0, 1, 1). In the Homestake mine also occur clear glassy well defined prismatic crystals of aragonite showing the same forms.

Mr. George Stowell, a student at the State School of Mines, found fine radiating groups of aragonite associated with chalcedony and pyritehedrons of pyrite, in the Homestake mine. The aragonite occurs in columnar forms ⅛ to ¼ inch in diameter which are arranged in sets radiating out from a center. Their surface is covered by minute prismatic crystals standing at angles of 35° to 45°, so that the whole gives a bristling appearance like the twig of a spruce. The surfaces of these prisms are rough and dull, so that no definite faces are apparent.

In the Standby Mine and the Golden Reward, aragonite is found as a vein filling. It is usually pure white, botryoidal or stalactitic in form and on fresh fractures shows a finely fibrous structure and strong silky luster. The shells of such animals as mollusks are usually calcium carbonate in the form of calcite, but the pearly layer—the so-called mother of pearl—as well as any slugs or pearls produced by these animals through irritants, are aragonite. The pearly layers are quickly destroyed and converted into calcite, but on many of the more recent fossils as those found in the Pierre shales along the Cheyenne and Missouri rivers, the pearly iridescent aragonite shell is still preserved.

Aragonite is readily confused with calcite, and distinctions are frequently very difficult to make. Silky lustered and fibrous forms are practically always aragonite. Columnar, vitreous forms are predominantly aragonite, but occasionally calcite. Large well defined crystals or coarse cleavable aggregates are always calcite. Aragonite tends to take on coralloidal shapes, pure white in color. These are very rare on calcite. Stalactites and stalagmites are common to both.

To be absolutely sure of the identity of the specimen when the crystal form cannot be identified, requires an examination of optical properties under a microscope. One of the following tests will also give good results in the hands of a competent observer:

Boil the finely powdered mineral in a dilute cobalt nitrate solution. Aragonite is quickly colored lilac and retains its color, calcite stays white, but upon persistent boiling turns blue.

Or, drop the finely powdered mineral in a solution of ferrous sulphate; aragonite will give a precipitate of flocculent dark greenish ferrous hydroxide, while calcite will cause a precipitation of yellow flocculent ferric hydroxide.

The exact conditions under which calcite or aragonite form, have received much study within the last few years, but are as yet incompletely understood. The more common interpretation is that the difference in crystal form is due to differences in temperature of the solution in which it forms. Thus it has been proven experimentally that from a bicarbonate solution we get at low temperatures a crystallization of calcite, but above 60° C., aragonite. But it is also probable that different forms may result from differences in the chemical character of the solution or of the precipitant. Thus ammonium or sodium carbonate precipitate aragonite from sea water, while calcite results from straight evaporations. The latter explanation seems to explain one set of conditions as exemplified in nature while, the first will afford the more satisfactory explanation in other cases.

Without a more systematic study of conditions in Wind cave the writer does not feel warranted in making a more definite statement regarding the origin of the calcite and aragonite there.

78. CERUSSITE $PbCO_3$.

The lead carbonate cerussite is quite widely distributed in occurrence in the Black Hills, but is restricted to the upper portions of lead-bearing veins in which the ore mineral is usually galena. This lead sulphide is readily attacked by ground water and altered to a sulphate or a carbonate. This change is accompanied by a corresponding alteration in other accompanying sulphides, such as pyrite and pyrrhotite, so that above the ground water level we find associated the lead sulphate, anglesite, and the carbonate cerussite, with such minerals as limonite and hematite. Other less important minerals occurring in this decomposed zone or gossan are pyromorphite (lead phosphate), vanadinite (lead vanadate), cerargyrite (silver chloride), plattnerite (lead oxide), matlockite (lead oxychloride) and other less noticeable minerals.

Such deposits occur at Carbonate, Galena, in the Ruby Basin, and have been especially mentioned in the previous discussion under galena.

Cerussite crystallizes in the orthorhombic system in crystals similar to those of aragonite. While it probably occurs in crystals in the Black Hills, there are none in the collection of the State School of Mines.

Usually this mineral is somewhat porous, but it grades into dense masses, which are white in color when pure, but are more frequently stained yellow, brown, or red by the accompanying iron oxides, or black by associated manganese oxides or graphitic material. Pure masses show a strong resinous to adamantine luster, impure masses are usually dull and earthy. Frequently pure masses show a tendency to a columnar or fibrous reticulated structure, which is never well developed in Black Hills specimens. The hardness is 3½, the specific gravity varies, depending on the purity. Pure cerussite from Carbonate has a specific gravity of 6.4.

This mineral is characterized by its great specific gravity, which is very noticeable even to inexperienced men, and by its ready effervescence when touched by a drop of acid. It is the heaviest of the carbonate minerals. A high percentage of impurities necessitates a chemical test for its identification. Native lead can readily be reduced from this mineral if it is mixed with a small amount of charcoal and five volumes of sodium carbonate and fused before the blowpipe or in an assayer's furnace. It is often associated with anglesite ($PbSO_4$), which may be distinguished by its lack of effervescence when treated with acids.

Cerussite is an important ore of lead, and frequently carries silver. Formerly it was mined to quite an extent at Galena, Carbonate, and Spokane, as has been noted in the discussion under galenite. An effort is being made at the present time to renew activities in these mining camps.

79. MALACHITE $CuCO_3Cu(OH)_2$.

Green carbonate of copper is a name quite frequently applied to this mineral by miners and prospectors. The copper sulphide minerals, such as chalcopyrite ($CuFeS_2$), bornite (Cu_3FeS_3), tetrahedrite ($4\ Cu_2S\ Sb_2S_3$), chalcocite (Cu_2S), etc., are very readily altered and oxidized by weathering action into such minerals as copper carbonates (malachite and azurite), copper oxides (cuprite and tenorite), copper silicates (chrysocolla), copper sulphate (chalcanthite) and even native copper itself. These minerals are usually restricted to that part of the vein or deposit above the ground water level. In small amounts they occur in many different localities in the Black Hills, for example, near Pactola, Sheridan, Fairburn, Pringle, Custer Peak, Bald Mountain, and in the Bear Lodge mountains.

Malachite is most common as an impure green and earthy staining or incrustation or vein filling, which is frequently mixed with the blue azurite. When pure it has a fine emerald to grass green color, a fibrous structure, and the appearance of velvety crusts. Fine specimens of this type come from the Blue Lead claim near Sheridan. Scott (44). also mentions that beautiful specimens occur in the Queen mine, near Fairburn. Such silky crusts have a hardness of 3.5 and a specific gravity varying from 3.65 to 4.1. The streak is pale green. Malachite will effervesce readily with acids which will distinguish it from other similar minerals.

80. AZURITE 2 $CuCO_3$ $Cu(OH)_2$.

This mineral is known to the prospector as blue carbonate of copper. It usually occurs as a blue staining or incrustation, dull to earthy in luster, associated with malachite. It is soft (3.5) and gives a pale blue streak. No crystals are known from the Black Hills.

Under ordinary atmospheric conditions azurite is unstable and quickly takes on water changing over to malachite. Its distribution and occurrence is the same as that of malachite.

81. BISMUTITE $Bi_2O_3CO_2H_2O$.

Amorphous, earthy to pulverulent masses of this basic bismuth carbonate have been described as occurring in a few places in the Black Hills. It is usually quite impure and soft, and varies in color from white, when pure, into yellow, brown, and red. It is usually quite heavy (6.5). It is readily confused with cerussite and a chemical test is necessary for certain identification.

It occurs in small amounts near Custer City, Fourmile, Galena, Carbonate, Hayward and Spokane.

GROUP OF OXYGEN SALTS.

b. SILICATES.

This group includes the minerals of greatest importance from the standpoint of abundance in the earth's crust. They are especially abundant in igneous and in metamorphic rocks, but are usually of very minor importance in sedimentary rocks with the possible exception of sandstones, conglomerates, and certain clays. Most of the silicates have formed in a fusion and hence have been subjected to great pressure and high temperature; a minor number of silicates have been formed as a result of regional or contact metamorphism; while a still lesser number result from ordinary weathering. The feldspars and hornblende, garnets and tremolite, and chlorite and talc, are examples respectively of each of the above groups.

Most silicates are characterized by their hardness, by difficult solubility and by their refractive character. This is especially true of anhydrous silicates. Hydrous silicates and a few anhydrous ones are usually soluble or partically so in acids, they frequently form gelatinous solutions, and often intumesce—i. e., swell and bubble—when they are fused.

Silicates are considered salts of hypothetical acids as follows:

Composition.	Acid.	Salt.	Example
H_4SiO_4	Orthosilicic	Orthosilicates	Zircon $ZrSiO_4$
H_2SiO_3	Metasilicic	Metasilicates	Tremolite $CaMg(SiO_3)_2$
$H_4Si_3O_8$	Polysilicic	Polysilicates	Orthoclase $KALSi_3O_8$
$H_2Si_2O_5$	Disilicic	Disilicates	Petalite $LiAL(Si_2O_5)_2$

A few minerals whose formulæ is very complex and not well understood form a fifth group—the subsilicates.

a. Disilicates—salts of H_2SiO_5.

82. PETALITE $LiAlSi_4O_{10}$.

This mineral has been found in the pegmatites of the Harney Peak region. Its association and occurrence have received indirect mention under the discussion of cassiterite. It is found associated with spodumene in the Etta Knob.

Petalite is a white mineral occurring in cleavable masses which are very hard (6) and fairly light (2.5 in sp. gr.). It is a very rare mineral and the only true disilicate in nature.

b. Polysilicates—salts of $H_4Si_3O_8$.

THE FELDSPARS.

This group of minerals comprises a series of alumino-silicates of soda, potash and lime. They are the commonest of the rock-making minerals and make up about 60° of the earth's crust. They all possess excellent cleavage and are equal in hardness to good steel. Usually we classify these minerals as orthoclases, or better, as potash feldspars, and as plagioclases or soda-lime feldspars. The following varieties are known from the Black Hills:

Potash feldspars:
    Orthoclase K Al Si_3O_8
    Anorthoclase $(KNa)AlSi_3O_8$.
    Microcline $KAlSi_3O_8$
Plagioclases:
    Albite $NaAlSi_3O_8$
    Oligoclase 3 $NaAlSi_3O_8+CaAl_2(SiO_4)_2$.
    Andesine $NaAlSi_3O_8+CaAl_2(SiO_4)_2$
    Labradorite $NaAlSi_3O_8+3\ CaAl_2(SiO_4)_2$

83. ORTHOCLASE $K_2OAl_2O_36SiO_2$.

The formula of this feldspar is frequently written $KAlSi_3O_8$. It very rarely is a pure alumina-silicate of potassium, but usually carries small amounts of sodium. It is quite abundant in the Black Hills and is the main constituent of such rocks as granite, syenite, trachyte, rhyolite, phonolite, tinguaite, which are quite common in different parts of the Hills. The last four rocks are frequently spoken of as "porphyries." Under this general term are included igneous rocks which are characterized by the presence of large crystals—known as phenocrysts—in a ground mass of smaller ones. The phenocrysts are very frequently orthoclase or another feldspar. Aegerite, and quartz also, occur as phenocrysts in rocks of the Northern Hills. Orthoclase occurring in this way is quite frequently well crystallized. Since it is quite resistant to weathering well defined crystals can often be broken out of the decomposed and soft matrix. Fine crystals can be obtained in this way at Black Butte, near Terry, Portland, Deadwood, Carbonate and elsewhere.

Crystal forms were first described by Irving from the Northern Hills (55). They usually show combinations of the following forms:

Prism a : b : α c (1, 1, 0)
Pinacoids α a : α b: c (0, 0, 1)
α a : b : α c (0, 1, 0)
Domes —a : α b: c (1, 0, 1)
—a : α b: 2 c (2, 0, 1)

On Black Butte excellent orthoclase crystals can be obtained which show all of the above forms and also in addition the prism 3a :b :∞c (1, 3, 0).

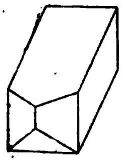
Fig. 53.

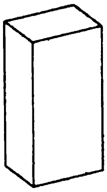
Fig. 54.

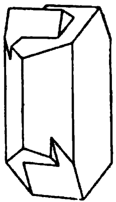
Fig. 55.

Orthoclase Crystals.

A beautiful crystal from Terry is made up of the prism (a :b :∞c), the pyramid (a :b :c) and the pinacoids (∞a :∞b :c) (∞a :b :∞c) and in appearance strongly suggests an orthorhombic prism modified by a pyramid. These Phenocrysts are usually of small size. Those near Black Butte reach an extreme length of one and one-half inch. Near Carbonate, crystals up to three and four inches in length have been found. These show two prisms (a :b :∞c) (3a :b :∞c), two pinacoids as above, the dome (a :∞b :2 c), and the pyramid (a :b :c).

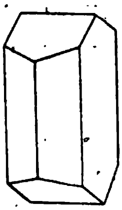
Fig. 56.
Orthoclase.

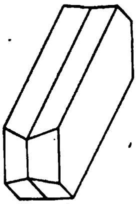
Fig. 57.
Albite Twin.

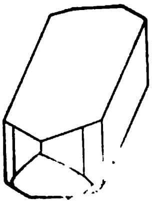
Fig. 58.
Orthoclase.

In some of the quartz porphyries we get square simple prisms made up of the unit prism (a :b :∞c) and the pinacoid (∞a :∞b :c).

The crystals from the Northern Hills are usually elongated parallel to the "a" axis. Crystals from Black Butte are elongated sometimes parallel to "a," also frequently parallel to the "c" axis.

Twins are exceedingly common, especially so-called "penetrations" twins. Frequently three or more individual crystals are intergrown. So-called "contact" twins also occur. These are so called because they suggest that the crystal has been cut in two along some crystallographic plane and that subsequently one-half had been rotated through 180°.

Orthoclase has excellent cleavage parallel to the pinacoid (αc:b:αc) and the basal pinacoid. The name orthoclase is due to the right angles shown by cleaving parallel to these two planes. Frequently there is a third cleavage parallel to the pinacoid (a:αb:αc) and rarely an indistinct prismatic cleavage additional. In the Harney Peak district the orthoclase usually shows only the two cleavages at 90°.

The orthoclase varies in color from white or gray into yellow and pink. The crystals near Terry and Black Butte are gray, those from Galena flesh colored. Clean, colorless orthoclase is often called sanadine or adularia. The streak is always colorless. Orthoclase is six in the scale of hardness and is only scratched with difficulty by good steel. The specific gravity of crystals is 2.64.

Orthoclase is insoluble in acids.

Crystals of orthoclase frequently contain a nucleus of microcline and occasionally of albite. The former has been noted in phonolites from the northern Hills (55). If appreciable percentages of soda replace the potash in orthoclase, the crystals became triclinic. To such the name anorthoclase is applied.

Orthoclase alters readily if acted upon by hot solutions to sericite, a mica, to Kaolinite, a clay, and to zeolites, silicates of potash soda, etc. Under ordinary atmospheric conditions it weathers more slowly into Kaolinite (china clay). Irving (51) mentioned the occurrence of rims of zeolites, especially natrolite, about orthoclase crystals from the northern Hill.

Orthoclase occurs massive in Harney Peak district in pegmatites. The author collected a fine crystal about 8 inches across from the Peerless claim. This shows the prism (a:b:αc), the pinacoids (αa:b:αc) and (αa:αb:c), and the orthodome (a:αb:c).

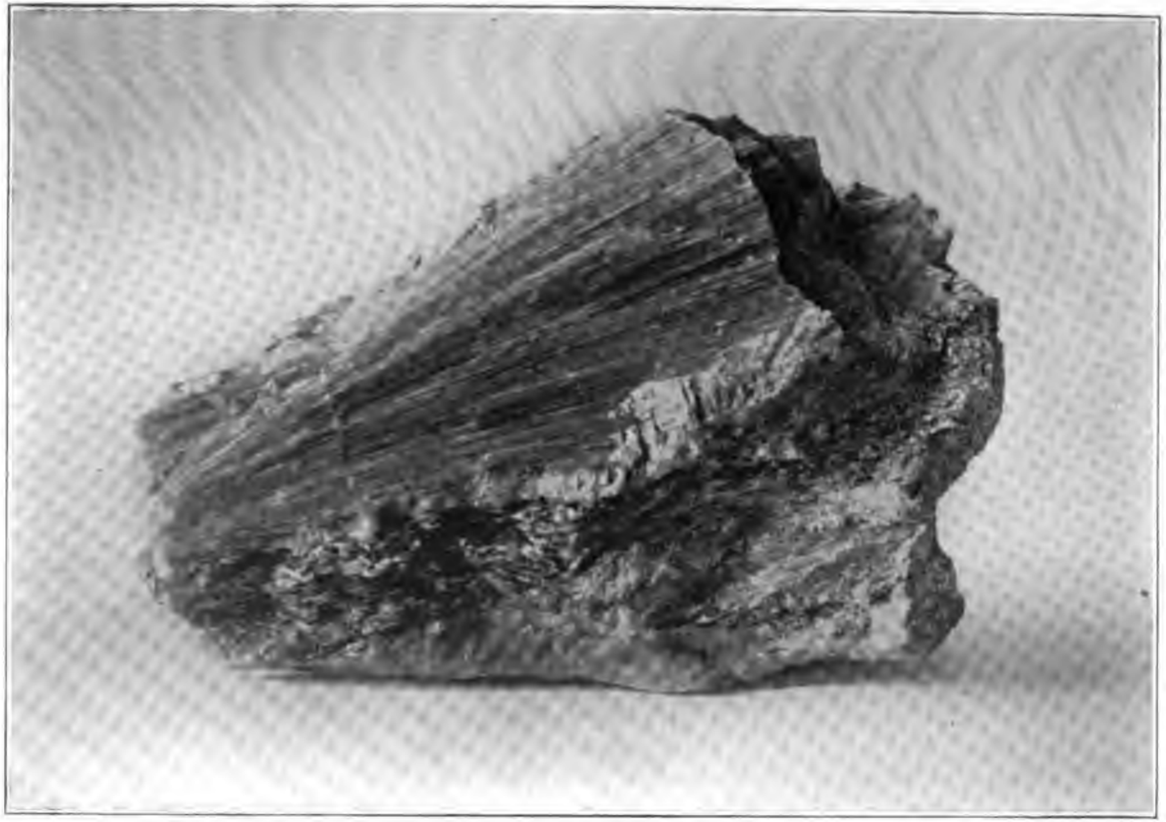

PLATE XVII: Actinolite and Phlogopite in Marble near Custer.

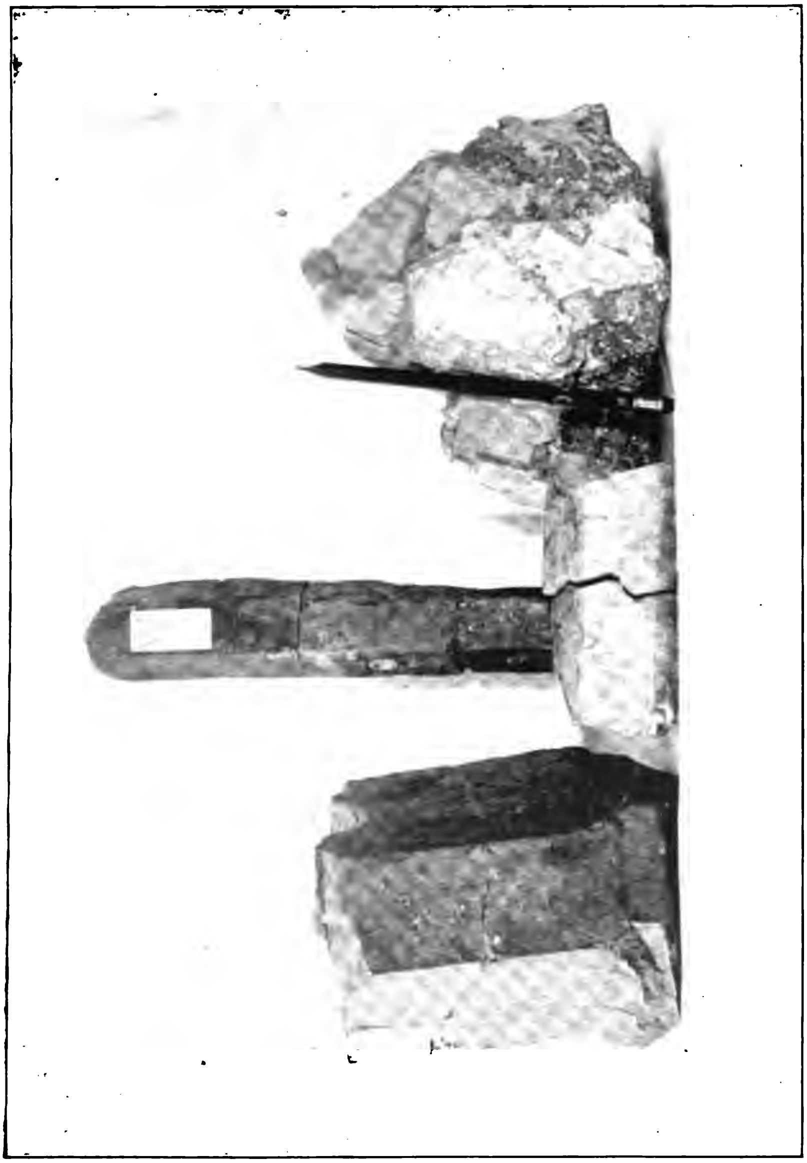

PLATE XVIII: Beryl Crystals from Custer. Mass with Struverite from Keystone.

84. ANORTHOCLASE $(KNa)_2OAl_2O_36SiO_2$.

This mineral has been identified with certainty only as a mocroscopic constituent of many of the soda rich rocks such as phonolites and triguaites. Here it occurs as phenocrysts easily mistaken for orthoclase. Such occur in the porphyritic phonolite of the Devils Tower. Much of the feldspar of the Harney Peak granite is anorthoclase. This resembles orthoclase in all characteristics and can only be distinguished under the microscope.

85. MICROCLINE $K_2O\ Al_2O_36\ SiO_2$.

The name, meaning slightly inclined, refers to the fact that the cleavage deviates only slightly from a right angle being 89° 30 min.

In the Harney Peak district and at Nigger Hill, microcline forms the abundant large masses of feldspar found in the pegmatites. These are often 5 or 6 feet across. It is usually massive and shows excellent cleavage almost at right angles. The color is yellowish, gray, or pink, the hardness is 6, and the specific gravity 2.65. As a microscopic constituent it is common in igneous rocks such as granites, phonolites, rhyolites, but can only be identified with certainty under the microscope, or by its crystal angles.

The crystallization is triclinic. The only crystals known from the Hills are made up of microcline in the center and orthoclase on the outside. These have been described under orthoclase.

86. ALBITE $Na_2O\ Al_2O_36\ SiO_2$.

This feldspar derives its name from its pure white color. It is very common in occurrence in the pegmatites and granite of Harney Peak and Nigger Hill, also as a microscopic mineral in the granites, seyenites, diorites, and schists of the Black Hills.

Crystals are rare. Usually the mineral occurs in pure white, gray, or yellow cleavable masses, which may have the appearance of being made up of thin slightly curved lamellæ. Clevelandite is another name applied to such cleavable masses. Fine tabular crystals of small size, but apparently simple twinned crystals occur at Bear Butte (?). Masses of albite usually show when turned in the light a series of fine striations or on some cleavages a series of parallel bands having luster of varying intensity. These are due to multiple or so-called "polysynthetic" twinning, i. e., twinning repeated a great number of times in the same direction. Albite has a pearly to vitreous luster and frequently a beautiful opalescent milky sheen. If this is well developed it is of value as a gem. Its hardness is 6, and the specific gravity is 2.62. It can be distinguished from orthoclase by color, cleavage (which is at 86°), and twinning striations. Exceptionally pure white and lamellar albite occurs in the pegmatite at the Bob Ingersoll claim.

87. OLIGOCLASE $3\ NA_2OAl_2O_3 6\ SiO_2+CaOAl_2O_3 2SiO_2$.

88. ANDESINE $Na_2OAl_2O_3SiO_2+3\ CaOAl_2O_3 2SiO_2$.

89. LABRADORITE $Na_2OAl_2O_3 6SiO_2+3\ CaOAl_2O_3 2SiO_2$

These plagioclases are of wide occurrence in igneous rocks, especially in basic ones such as diorites. Such occur in the vicinity of Deadwood.

These minerals usually occur in minute grains of gray color, which show cleavage at about 86°. They are all 6 in hardness and vary from 2.7 to 2.8 in specific gravity. Polysynthetic twinning, when present, is manifested as a series of striations or a series of parallel light and dark bands. Occasionally the plagioclases, especially labradorite, show a beautiful iridescent play of color on the surface. If either of these are present, it will serve as a means of distinction from orthoclase. Exact identification can only be made by means of the microscope or by a quantitative chemical analysis; for this reason they merit no further description.

They are known in diorites from the vicinity of Deadwood, in amphibolites from the central Hills, and in a series of basic igneous rocks near Sundance. Oligoclase is also quite common in certain pegmatites, often in large masses as in the Etta, the King Mica, the Bob Ingersoll and other claims.

90. PERTHITE.

The name perthite or microperthite is applied to certain intergrowths consisting of parallel lamellæ of two feldspars, frequently albite and orthoclase.

Such material occurs at Harney Peak and in the Bear Lodge. This does not differ in appearance and characteristics from other feldspars and can only be identified with certainty microscopically.

THE FELDSPATHOIDS.

This group of minerals comprises alumino-silicates of potash and soda and lime, meta and ortho silicates respectively, and analogous to feldspar in composition. While the latter minerals occur in many igneous rocks with quartz, feldspathoids are found only when the latter mineral is absent. As a rule these minerals are microscopic in occurrence and no specimens can be obtained for study except in thin sections. The following feldspathoids occur in the Black Hills:

91. LEUCITE $KAl(SiO_3)_2$ (?)
92. NEPHELITE $NaAlSiO_4$
93. SODALITE $3\ NaAlSiO_4 + NaCl$
94. HAUYNITE $3\ NaAlSiO_4 + CaSO_4$
95. NOSELITE $3\ NaAlSiO_4 + Na_2SO_4$

Practically all of these minerals are harder than glass, and if boiled with hydrochloric acid will form a stiff transparent jelly. Nephelite is hexagonal and looks very much like quartz under the microscope; the other minerals are isometric, and if developed in fair size will show a series of practically circular white or gray grains in the igneous rock. Such crystals are described by W. S. Tangier Smith (84) from the vicinity of Nigger Hill and Sand Creek on the Wyoming line and also by Irving (55) from the northern Black Hills. Smith also describes pseudomorphs of orthoclase and muscovite after leucite from Nigger Hill. Such crystals also occur in the vicinity of the Devils Tower and Aladdin.

In the great majority of cases, however, these minerals are only visible under the microscope. Thus nephelite, which is quite widespread, can never be recognized with the unaided eye. The rock making up Ragged Top, Spearfish Peak, Sugar Loaf, the Devils Tower, and other less well known mountains, contains nephelite in fair amounts as a microscopic constituent. These rocks are called phonolites and it may be of interest to note that the first phonolite found in the United States came from the northern Black Hills (1). The other minerals occur as accessories in microscopic amounts in nephelite rich rocks.

No true leucite has been found, but the abundance of pseudomorphs made up of orthoclase and muscovite prove the probability of its existence.

F. C. Smith (46) mentions the occurrence of leucite bearing rocks in the northern.Hills, but as has been shown subsequently (55) another feldspathoid—probably noselite—was mistaken for leucite.

THE PYROXENES.

This group includes a series of metasilicates of calcium, magnesium, iron, aluminum, sodium, and lithium. Those occurring in the Black Hills are monoclinic in crystallization, and are characterized usually by short, stocky crystals with prismatic cleavages at angles of about 93° and 87°.

The following varieties occur in the Black Hills:

Diopside $CaMg(SiO_3)_2$
Augite CaMgFeAl metasilicate
Aegerite $NaFe\ (SiO_3)_2$
Spodumene $LiAl\ (SiO_3)_2$

96. DIOPSIDE $CaMg\ (SiO_3)_2$

This mineral has been reported from the Black Hills, but no specimens are on hand for description. When alumina becomes a prominent constituent we apply the name augite. The latter mineral is of widespread occurrence in the Black Hills and may be readily confused with diopside.

97. AUGITE.

This mineral is usually considered a mixture of CaMg $(SiO_3)_2$ and (MgFe) $(AlFe)_2$ SiO_6, so that by a decrease in the alumina content it passes into diopside and by an addition of soda into ægerite. Augite, intermediate in composition between true augite and ægerite, is frequently spoken of as ægerine-augite. This latter mineral is especially common in the Black Hills region. It usually occurs in minute greenish black crystals in igneous rocks, especially the porphyries in the northern Black Hills, and the igneous rocks of the Bear Lodge district. Crystals tend to be equidimensional and usually show good prismatic cleavage at angles of about 87° and 93°, which may be visible under a pocket lense. It is 5.5 in hardness, and gives a pale greenish streak.

Aegerite, which occurs in about the same rocks, tends to be needle-like and fibrous, which will serve to distinguish it from ægerine-augite. According to Irving (55) the ægerine augite of the northern Hills occurs in tabular to square crystals showing the prism a :b :∞c (1 1 0) and the pinacoids a :∞b :∞c (1 0 0) and ∞a :b :∞c (0 1 0). The basal pinacoid ∞a :∞b :c (0 0 1) and more rarely the pyramid a :b :c (1 1 1) are also present.

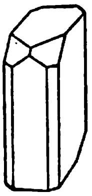

Fig. 59. Augite.

These augite crystals frequently show a zonal structure which becomes visible under a strong pocket lens. The central portion is usually lighter than the outside and under the microscope proves to be augite, while the dark outer rim is rich in soda, and is ægerine augite.

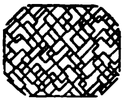

Fig. 60. Cross section of Augite, showing cleavage.

In the Bear Lodge district W. S. Tangier Smith (84) found some rocks called pyroxenites, which are essentially made up of augite. The augite in these differs from the above in being lighter in color (usually dark green) and by occurring in fair sized grains.

Among the Precambrian rocks of the Black Hills, for example near Deadwood, Rochford, Mystic, Silver City, and elsewhere, we get rocks called amphibolites. These rocks are characterized by a preponderance of amphiboles such as hornblende and actinolite. Originally they were rich in augite, but the latter mineral has, as a result of excessive pressure, during metamorphism, been recrystallized into an amphibole. Thus frequently we can find in a thin section a grain of hornblende with a nucleus of augite still preserved, giving us the clue to the origin of the amphibole. This change was first observed in rocks from the Ural mountains and hence this alteration process was called uralitization, and the secondary amphibole was called uralite.

98. AEGERITE $Na\ Fe\ Si_2O_6$

This mineral is an important constituent of many of the soda rich rocks of the northern Black Hills, such as phonolites, tinguaites, ægerite-quartz porphyries, grorudites, and also occurs to some extent in similar rocks and in nepheline syenites in the vicinity of the Bear Lodge mountains.

Aegerite occurs as minute deep greenish black shining needles, which have an almost metallic luster. Ofter they tend to fray out at each end, suggesting the end of a broom. Occasionally they are so small in size that they give the whole rock a uniform greenish color. They are 5.5 in hardness and leave a very pale greenish streak.

99. SPODUMENE $LiAlSi_2O_6$

The Harney Peak district is one of the world's famous localities for the occurrence of this mineral. This is especially true on account of the immense size of some of the crystals found in the Etta Knob, which have already been mentioned in the discussion of cassiterite. These crystals stand unsurpassed for size on earth. The mineral occurs in pegmatites, which as has already been shown (see under cassiterite) represent those portions of an igneous fusion rich in volatile constituents from which the true granitic rock has crystallized. These pegmatites before solidification are very fluid and are rich in easily fusible and volatile constituents such as water, boron, tungsten, chlorine, etc., which are held in solution either as gases or liquids by great pressure. Such watery solution or fusions offer little resistance to the force of crystallization and if sufficient time be allowed this force may govern the arrangement of minute crystal particles for such distances as fòrty-two feet, which is the longest spodumene crystal recorded from the Black Hills. A number attaining thirty feet in length are known. In diameter these vary from three to four feet. Mr. Samuel Scott (oral communication to Dr. O'Harra) records one spodumene crystal with a diameter of 64 inches. "They stand in the midst of the feldspars and quartz in all directions, and cross and intersect each other at all angles. In one of the open cuts these crystals standing in the sides look like huge timbers set up to sustain the rock." (12)

The amount of mass represented by one of these crystals is stupendous. Thus a single crystal 36 feet long, and 3 feet in diameter will weigh approximately 50,300 pounds or slightly over 25 tons. When we remember that the deposition of this great amount of mass was controlled by molecular forces which not only had to control the direction and manner of deposition of each crystal particle of the spodumene, but had to exclude all foreign substances as well, the great size and purity of these crystals seems not only remarkable, but almost impossible.

These crystals are essentially simple prismatic. Terminal faces have never been observed. All show excellent cleavage parallel to the prism and hence at practically right angles (93°). Cleavage is also shown parallel to the pinacoid ($\alpha a : b : \alpha c$) and occasionally parallel to ($a : \alpha b : \alpha c$).

The luster of the crystals when fresh is vitreous inclined towards pearly, but after exposure becomes somewhat dull silky. The hardness is 6.5, but is quickly reduced by weathering. The specific gravity of select specimens is 3.1 to 3.2.

The color is grayish white usually, but cream colored specimens and even pale green ones are common. Along the cleavage cracks radiating clusters of minute cassiterite crystals are frequent as are also minute dendrites of pyrolusite.

The spodumene usually carries soda which replaces lithia. No complete analyses are available, but two spodumenes from the Harney Peak district gave Professor Coolbaugh of the South Dakota State School of Mines 1.18% and 3.56% of LiO_2 respectively. An analysis of a specimen carrying 6.16% LiO_2 is cited by Dr. O'Harra. (65)

The spodumene alters into a beautiful fibrous aggregate of albite and muscovite to which the name cymatolite has been applied. The fibers are usually wavy in appearance and have a strong silky luster and pure white color. Tendency towards this alteration product is shown by the appearance of the silky luster and poor fibrous structure on slightly weathered spodumenes. In some specimens a peculiar pale bluish green color is brought out after slight weathering, which may be due to staining by cuprocassiterite.

Spodumene is of value as a source of lithia, which is mainly used for medicinal purposes. Several hundred tons of this mineral were produced during each summer by mines near Harney Peak in the past.*

The occurrence of spodumene has been indirectly discussed under the description of cassiterite, but the following localities deserve special mention: The Etta mine near Keystone, the Wood Tin, the Boomerang, and the Sunday Fraction, south and southeast of Keystone, and Palmer Gulch, five miles southeast of Hill City. In addition spodumene occurs on many other claims near Keystone, and also near Glendale, Custer, and Hill City. It is only known in pegmatites, and occurs also in some of these in the Tinton district west of Deadwood.

THE AMPHIBOLE GROUP.

Under this group are included a series of metasilicates of Ca, Mg, Fe, and Al and rarely of the alkalies, which are hence the same as the pyroxenes in composition, but which differ in crystallization and crystal habit.

Amphiboles are usually fibrous, or slender prismatic, have prism angles and cleavages of 124° and 56°, and are more common than the pyroxenes, especially in metamorphic rocks.

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*For a more complete description see V. Ziegler's "The Lithia Deposits of the Black Hills." Eng. & Min. Jour., Dec. 6, 1913.

The following amphiboles occur in the Black Hills:

Tremolite Ca $Mg(SiO_3)_2$
Actinolite $Ca(MgFe)_3(SiO_3)_4$
Cummingtonite $MgFe(SiO_3)_2$
Hornblende Complex CaMgFeAl silicate.

100. TREMOLITE Ca $Mg(SiO_3)_2$

Small colorless prismatic crystals usually arranged in radiating aggregates and individually showing a columnar structure, occur in the Homestake mine. The cleavage is well developed and the large (124°) cleavage angles are readily identified under a lens. The specimens were imbedded in soft bright green chlorite. They are about 6 in hardness, cutting glass readily and their specific gravity determined in heavy solutions is 3.02.

Much of the amphibole so common in the ore of the Homestake was originally referred to tremolite, but Sharwood has recently shown (102) that it is cummingtonite.

No other occurrence of tremolite in the Black Hills is known to the writer.

101. ACTINOLITE Ca $(MgFe)_3(SiO_3)_4$

This is the most abundant amphibole of the Black Hills region. It is an especially important constituent of the schists and amphibolites of the central area of the Black Hills. Fibrous dark green radiating aggregates often with a silky luster occurs in some mines, as the Standby and the Homestake for example, densely intergrown with chlorite. The fibers are often so intergrown as to suggest a matted felt-like appearance. The so-called "actinolite schists," frequently known as hornblende to the miners, show this matted structure so well developed that they offer great resistance to the miner by their toughness caused by the interlocking fibers. The actinolite is about 3.3 in specific gravity and about 5.5 in hardness. Frequently a distinctly long fibrous development is shown, often shading into asbestos. Such asbestos—grayish white in color and made up of long fibers—occurs north of Rochford. This is also known from the vicinity of Iron Mountain in Custer County.

About eight to ten miles northwest of Custer occurs a marble mentioned under the discussion of calcite. This is quite rich in beautiful columnar masses and also fibrous radiating often densely matted aggregates of actinolite. These are a bright green in color and give a fine contrast with the pure white marble and the brown flakes of the associated phlogopite (mica). These columnar aggregates attain a length of ten to twelve inches, they are 6 in hardness, and have a specific gravity of 3.2.

Most of the amphibolites of the Black Hills are rich in actinolite which has been derived in large part from the alteration of augite due to metamorphism. These rocks are known to the miners under the term, diorite in the vicinity of Lead, Deadwood, Rochford, Mystic, Silver City, etc.

102. CUMMINGTONITE Mg Fe $(SiO_3)_2$

Sharwood (103) has lately shown that this mineral is the common amphibole of the Homestake mine rather than tremolite or actinolite. It has not come to the writer's attention from elsewhere in the Hills.

The cummingtonite of the Homestake mine consists of light brownish fibrous and radiating masses. In the less oxidized ore the amphibole is nearly black or dark green and is also associated with other minerals as biotite and chlorite. The hardness of cummingtonite is about 5.5 and its specific gravity as determined by Sharwood (103) varied from 3.28 to 3.387. Gradations are shown into soft asbestos, with fine silky fibers, white to light gray in color, some of them eight inches long (103).

The following analyses are by Sharwood:

	I.	II.	III.	IV.
SiO_2	52.36	50.36	45.66	46.8
Al_2O_3	1.54	1.86	6.87	5.02
FeO	33.76	34.62	31.40	33.0
MnO	0.45*	0.62	....	0.31
MgO	8.10	9.86	9.20	9.50
CaO	0.94	trace	1.04	1.16
Na_2O	..**	0.74	0.50	....

K_2O	....	trace	0.73	....
H_2O	1.68	....	0.14	....
Ignition loss	....	0.73	2.05	2.90
Fe_7S_8	0.89	....	....	....
	100.12	98.78		
Sp. gr.	3.387	3.28		

I.—Brownish white radiating fibers.
II.—White asbestos.
III. and IV.—Impure dark radiating masses.

The analyses of the purer specimens (I. and II.) show that this mineral is essentially a silicate of iron and magnesia which would make it cummingtonite rather than tremolite or actinolite.

103. HORNBLENDE.

Varieties of amphiboles rich in alumina are usually included under this term. In the Black Hills hornblende occurs in igneous rocks of the northern Hills such as andesites, diorites, syenite porphyries, dacites, etc. In the Bear Lodge district hornblende also occurs in igneous rocks such as phonolites, syenites, mozonite porphyries and others. Amphibolites, both in the Black Hills proper and in the Bear Lodge and Nigger Hill districts carry abundant hornblende.

Well defined crystals have only been found in the hornblende of the porphyries of the northern Hills. In these Irving (51) identified the following forms: The prism a:b:∞c (110) and the pinacoid ∞a:b:∞c (010) terminated by the dome ∞a:b:c (011).

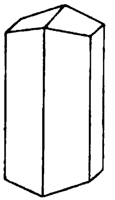

Fig. 61

The common color of the hornblende in the igneous rocks of the northern Hills and in the amphibolites is green of a dark shade, frequently almost black. In certain phonolites and in a nephelite-syenite from Mineral Hill, Wyoming, the hornblende is dark brown in color.

The hardness of hornblende is 5.5 and the specific gravity varies from 3.1 to 3.3. The luster is vitreous and the streak white or pale gray.

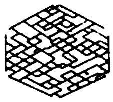

Fig. 62. Section of Amphibole, showing cleavage.

Hornblende has prismatic cleavage at angles of 124° and 56° respectively, which will distinguish it from augite and ægerite. Fibrous structure is characteristic of actinolite and serves to distinguish it from hornblende.

As a result of weathering the amphiboles are readily decomposed to chlorite and iron oxides.

104. BERYL $Be_3Al_2(SiO_3)_6$

Sodium, cæsium, and lithium frequently replace part of the beryllium in beryl. Minute amounts of water are also often present.

Beryl is another mineral which occurs in well defined crystals in the Harney Peak region. These attain large size, some from the vicinity of Custer, which are in the collection of the South Dakota State School of Mines, measure six inches in diameter. Another about twelve inches long is three inches in thickness. Irregular masses of greater size than these are common in many of the pegmatites.

The largest crystal in the State School of Mines collection is a simple hexagonal prism, six inches across. It has no terminations, being broken off on both ends. This crystal as well as several of the smaller ones show fractures which have been cemented subsequently, or as we say, "healed," by quartz bearing solutions.

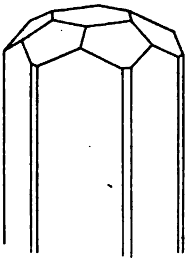

Fig. 63.

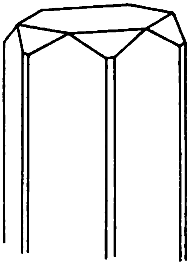

Fig. 64.

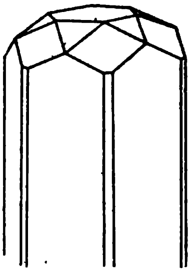

Fig. 62.

Small crystals, about one to three inches in diameter, are prismatic, frequently showing distinct terminations. For convenience these crystals may be divided into three types.

The first type is made up of the hexagonal prism a:∞a:a:∞c (1010), the basal pinacoid ∞a:∞a:∞a:c (0001) and minute faces of the second order hexagonal pyramid 2a:2a:a:2c (1121).

The second type is made up of the same three forms, but the pyramid faces are well developed and large, while the basal pinacoid is small. These crystals also show the second order prism 2a:2a:a:∞c (1120) occasionally, but always in small development.

A third type of crystals is made up of the above forms. The hexagonal prism of first order predominates, its edges are truncated by minor development of the second order prism. The terminations consist of an equal development of the pyramids 2a:2a:a:2c (1121) and a:a:∞a:c (1101) and a very minor development of the basal pinacoid.

Those crystals that show the second order prism faces usually have these deeply striated parallel to the vertical (c) axis.

A crystal of the third type reaching an extreme length of 10¾ inches and a diameter of two inches shows deep etching, and on the pyramid faces shows minute pentagonal protuberances, whose axis of symmetry lies in the plane passing through the c axis.

No cleavage is apparent in the beryls except an indistinct one parallel to the basal pinacoid, which is not always present. Many crystals have excellent parting, usually showing in slightly curved planes, in two directions at right angles to each other and parallel to the c axis. Others show a decided parting parallel to an oblique plane which makes an angle of about 60° with the vertical axis. The surfaces yielded by a fracture are usually uneven and show a tendency towards conchoidal planes.

Beryl is about 8 in hardness and scratches quartz. The specific gravity of crystals is 2.64.

In color beryl varies from clear yellowish white and glassy, into pale yellow or light amber colored masses or crystals. Green of various shades is the most common, especially a light sea green. A fine beryl crystal from the vicinity of Custer is milky white in color, is traversed by red seams and veinlets of iron oxide, and is very weakly translucent. Clear transparent varieties are not common. When they do occur they are on a poor colored beryl usually on yellowish white ones. Frequently beryl crystals that are amber colored on the outside are sea green when broken, showing that the brown color was in all probability due to alteration or staining. The common luster is vitreous, especially on green varieties, the colorless varieties commonly have a waxy luster. The color is practically never uniformly distributed, but varies decidedly in shade and intensity. Certain clear and pure colored varieties of beryl are used for gems and are quite valuable, but as far as the writer knows no gem material has been found in the Black Hills.

Beryl may be found in considerable abundance in many of the pegmatites of the Harney Peak and the Nigger Hill districts. Good crystals come from the White Spar Mica mine, the Hitchcock Mica mine, and other mica properties near Custer. Beryl also occurs in the Etta, Hugo, Bob Ingersoll and the Peerless claims near Keystone. In the Etta claim it is common massive carrying small amounts of struverite as inclusions. Beryl also occurs in fine crystals in the Dan Patch claims near Keystone.

GARNET.

Under garnet we include a series of orthosilicates of Ca Mg Fe Al and more rarely Mn Cr and Ti. We name the garnet according to the constituents present. Seven varieties are usually recognized, of which the following occur in the Black Hills:

105. ALMANDITE $Fe_3Al_2(SiO_4)_3$
106. ANDRADITE $Ca_3Fe_2(SiO_4)_3$
107. GROSSULARITE $Ca_3Al_2(SiO_4)_3$
108. SPESSARITE $Mn_3Al_2(SiO_4)_3$
109. MELANITE (variety of andradite)

None of these garnets are ever absolutely pure in composition, but contain small amounts of molecules characteristic of other members of the group.

Garnets are known to occur under the following conditions in the Black Hills:

a. As an accessory constituent in igneous rocks.
b. As a constituent of pegmatites.
c. As a mineral produced by contact metamorphism.
d. As a constituent of regionally metamorphosed rocks such as schists and gneisses.
e. In placers.

GARNET IN IGNEOUS ROCKS.

Almandite, andradite, and spessartite are the varieties known to occur in igneous rocks. They are usually microscopic in size and only of very minor importance in such rocks. They occur in some of the more coarsely crystalline igneous rocks as the granite on Little Elk Creek, and granitic rocks in the Bear Lodge district. Occasionally such a garnet may be visible to the naked eye. They are red in color, have strong vitreous luster, and usually show circular cross section. Igneous rocks that are rich in the feldspathoids such as nephelite and leucite frequently carry notable amounts of the garnet andradite. This variety of andradite has on account of its black color been called melanite.

It has been found by Irving (55) in the Phonolite from Ragged Top Mountain. It also occurs in Nephelite syenites, phonolites, ijolite, and in rocks so abundant in melanite as to lead W. S. Tangier Smith (84) to apply the name "nephelite-garnet rock," in the Nigger Hill area. Related garnetiferous rocks also occur in the Bear Lodge district.

b. Garnets in pegmatites.

In the pegmatites of the southern Hills garnets often attaining large size are quite common. Spessartite is the common variety, but almandite is also known sometimes in considerable abundance. The common crystal form of these garnets is the trapezohedron. A fragment of a crystal in the museum of the State School of Mines showing 5 or 6 trapezohedral faces only, has an extreme diameter of 7¼ inches. This upon inspection of the crystal faces appears to be a pure garnet crystal dark brownish black in color, but on the fractured side shows an intergrowth of lamellæ of quartz and red granular garnet arranged in a radiating structure. Smaller dark brown garnets up to 5½ inches in size enclose perfect small mica (muscovite) crystals, or in several cases partially enclose well developed three-sided tourmaline crystals. The dark brown color of these garnets nearly always gives place to a bright red in the interior.

Sharwood (103) quotes the following analysis of brown garnet from the southern Hills, evidently a garnet from pegmatite:

SiO_2	36.4%
Al_2O_3	22.2
FeO*	26.8
MnO	12.9
MgO	trace
CaO	trace
K_2O Na_2O	not determined
H_2O	0.75

Another garnet from the southern Hills gave Sharwood 16.7% MnO.

Grossularite occurs also as minute red crystals, usually appearing as mere dots, included in the blue apatite of certain pegmatites.

c. Garnets produced by Contact metamorphism.

Grossularite has been mentioned as occurring in slightly contact metamorphosed zones accompanying some of the pegmatite intrusions in the Harney Peak region under the discussion of cassiterite. An enrichment in grossularite is caused in several cases where the pegmatites have cut through basic schists.

d. Garnets in metamorphic rocks.

Garnets occur in great profusion in many of the schists of the central Black Hills, and in lesser amount in amphibolites and in quartzites. In the latter two rocks the garnets are small in size, usually a millimeter or two in diameter. The common color is red. In a micaceous schist near Key-

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*No separation made from Fe_2O_3.

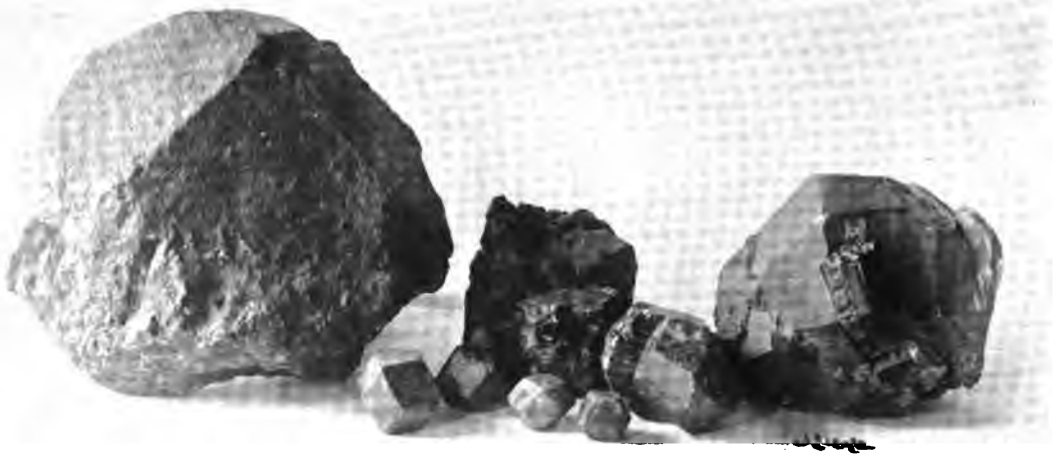


PLATE XIX: Garnets.
Front row from Schists, back row from Pegmatites,
Harney Peak District.
(⅓ natural size.)

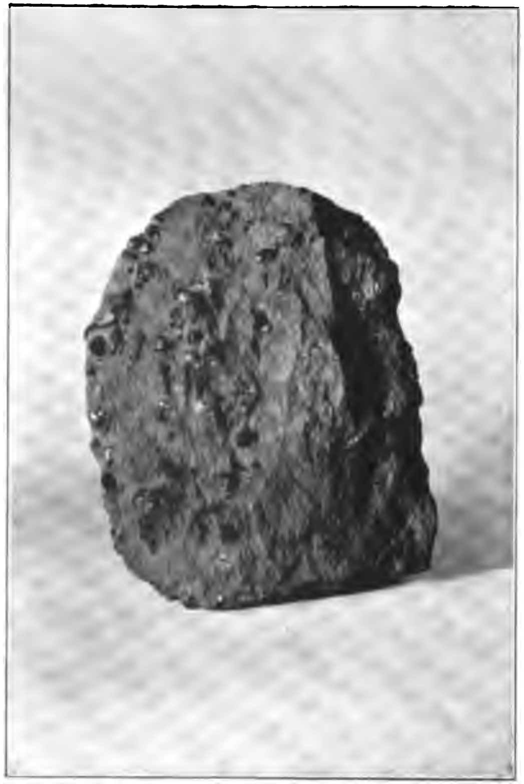
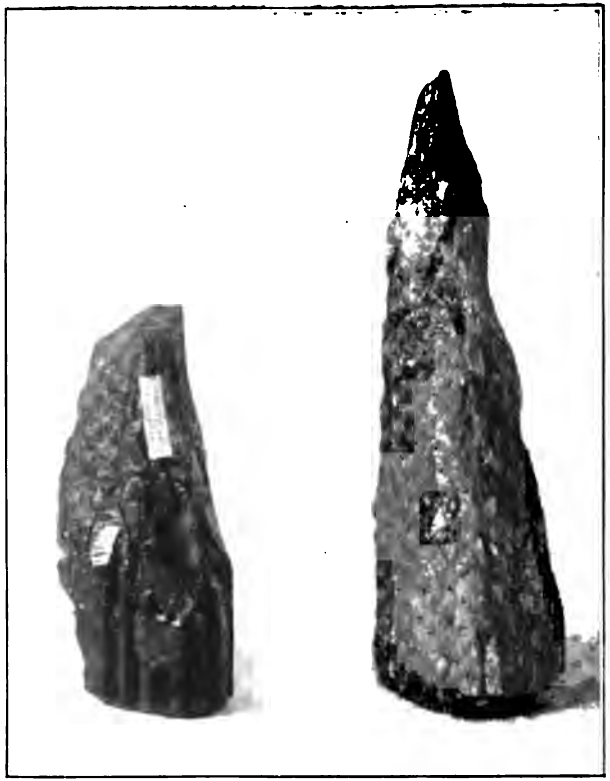


PLATE XX:
Garnets in Schist,
Harney Peak District.
(¼ natural size.)



Tourmaline and Pseudomorph of
Muscovite and Quartz near
Custer.
(½ natural size.)

stone the garnet, usually almandite, occurs in minute clear red crystals, made up of dodecahedrons modified by a trapezohedron. This is a common type and is quite widespread in occurrence about the Harney Peak area and also about the volcanic rocks of the northern Hills.

In similar schist near Custer we get crystals of the same type, about ½ to ¾ inch in diameter, and black on the surface, but red and granular on fresh fractures. These still show the same two forms—the dodecahedron modified by the trapezohedron. In the vicinity of Custer elsewhere the garnets attain a diameter of one to 2½ and even 3 inches. These are brownish black in color and show the dodecahedron only. This is well developed and but slightly distorted. None of many large crystals examined showed the modification by the trapezohedron which is always present on the minute crystals.

Fine clear crystals of almandite garnet occur near Elephant Gulch, west of Custer, and specimens suitable for gems have occasionally been found here.

In the Homestake mine, garnet is of frequent occurrence, especially in chlorite schist. A specimen in the collection of the State School of Mines shows several reddish brown resinous lustered garnets of dodecahedral habit. These are about ½ inch in diameter and are crushed and traversed by seams of chlorite and quartz.

Sharwood (103) gives the following analysis of garnet from the Homestake:

SiO_2	38.66%
Al_2O_3	24.03
FeO	28.10
MnO	3.90
MgO	2.71
CaO	0.00
H_2O	2.35

This would hence be an almandite garnet with small amounts of MnO and MgO replacing some of the ferrous iron.

c. Garnet in Placers.

Garnets are heavy minerals (specific gravity 3.5) and are very hard (7—7.5), hence they are readily concentrated in placers. They are very abundant in the gravel of many streams, especially in the central and southern Black Hills.

The specific gravity of the garnets depends on composition. Grossularite (pink) is 3.6, almandite 3.95, andradite 3.78, and spessartite is 3.92.

The granular structure, isometric crystals, lack of cleavage, great hardness, and fair specific gravity, together with the usual red or brown color serve to distinguish the garnets from other minerals.

110. WILLEMITE Zn_2SiO_4 ?

This zinc silicate was identified by Professor Jenson, formerly in the State School of Mines, for Mr. Samuel Scott (44) as occurring in the vicinity of Custer. This occurrence is doubtful.

111. ZIRCON $ZrSiO_4$

This mineral occurs in two ways in the Black Hills—as a microscopic constituent in igneous rocks, and in placers and gravels derived from their alteration.

Its distribution is summarized with other minerals under the discussion of cassiterite.

Zircon occurs in very minute grains in the granite of the Harney Peak and also in the Nigger Hill district. In pegmatites the crystals are occasionally large enough to be visible, but are never more than a small fraction of an inch in size. The crystals are usually well defined tetragonal prisms capped by a pyramid. They are very hard (7.5) and hence will scratch quartz. They are fairly heavy and are concentrated in small amounts with other heavy and resistant minerals in placers. The common color is brown of a medium shade. They are nowhere abundant.

112. TOPAZ $Al\ (FOH)_2\ Al\ SiO_4$

This fluosilicate of aluminum has been mentioned by W. S. Tangier Smith as occurring in the Nigger Hill district in Wyoming (84). Topaz is a very characteristic mineral in tin deposits elsewhere, but up to its finding by Mr. Smith was thought to fail in the Black Hills region.

No specimens are available for study or description.

113. ANDALUSITE Al_2SiO_5

The mineral is another important mineral in the pegmatites of the Harney Peak district and in common with the associated minerals frequently occurs in crystals of large size.

The best crystals were found in pegmatites in the vicinity of Oreville and in irregular shoots near Harney. These are coarse flesh red prismatic forms. They occur as an irregular aggregate of several crystals 3 to 5 inches in diameter, each made up of the orthorhombic prism a:b:∞c (110) and the pinacoid a:∞b:∞c (100). Most of them have no terminations; one crystal, however, shows a small development of the basal pinacoid ∞a:∞b:c (001), and shows the dome ∞a:b:c (011). These crystals have imperfect cleavage parallel to the prism face, and to the pinacoid a:∞b:∞c. They are about 7 in hardness, hence the same as quartz. Their specific gravity is 3.5. The luster varies from dull to vitreous, inclined towards resinous.

Andalusite also occurs frequently as pink to flesh red masses irregularly intergrown with quartz, muscovite and albite in some pegmatites. In these masses cleavage is not very apparent, they are usually granular in appearance and suggest garnet strongly, from which they differ in being far lighter in color. Andalusite is also lighter in specific gravity, but this will usually not be apparent to one inexperienced in handling minerals. Good massive andalusite occurs in some of the pegmatites on Summit Peak near Hill City.

114. ZOISITE $Ca_2(AlOH)Al_2(SiO_4)_3$

This mineral is only known as a microscopic constituent of some of the igneous rocks, and occurs as a decomposition product of plagioclase feldspars in small amounts. It is found thus in the so-called amphibolites of the Black Hills.

115. EPIDOTE $Ca_2(AlOH)(AlFe)_2(SiO_4)_3$

This mineral is a somewhat common alteration product of plagioclase feldspars and some of the iron bearing silicates. It is found quite widely distributed throughout the Black Hills, but is usually very impure, being mixed with other decomposition products such as chlorite, talc, kaolin, sericite, etc. Some of the so-called amphibolites, i. e., dense dark colored metamorphosed rocks of the Algonkian area, frequently show this mineral well, but impurely developed. It gives the rocks a peculiar green colored staining which varies from dark green to a pale odd yellowish green. The green color is especially well shown by boulders which have been transported some distance. Beautiful yellowish green fibrous to columnar epidote occurs in some quartz veins near Harney. The luster varies from dull to vitreous, the streak is pale greenish, the hardness 6, and the specific gravity 3.25.

As a microscopic constituent, as already stated, it is quite common in weathered basic igneous rocks.

Scott (44) mentions beautiful green crystals of this mineral from the Tin Hill and Riverton Tin mines near Harney City.

116. PIEDMONTITE $(CaFe)_2(AlOH)\ (AlFeMn)_2(SiO_4)_3$

This mineral is about the same in composition as epidote, but carries manganese as an additional constituent. Piedmontite occurs sparsely as a filling of minute fissures in obsidian—volcanic glass—near Roubaix.

It is clear pink in color, and is a mineral with especially well developed pleochroism. Its color by transmitted light, depending upon direction, is bright rose red, pale pink, or lemon yellow.

It has as yet been found nowhere else. The specimens available are of too minute size to allow further study.

117. CALAMINE $Zn_2SiO_4\ 2H_2O$.

The only place this zinc silicate has been found so far is in the Tiger Mine, near Hayward, which has already received mention in the discussion of sphalerite and galenite. The calamine occurs as an alteration product of sphalerite above the ground water level, and is associated with smithsonite.

Calamine occurs as drusy microcrystalline coatings in small stalactic forms. They are not quite hard enough to cut glass (H 5). The specific gravity is 3.371, as shown by heavy solutions. The color is colorless to rusty; the luster adamantine to dull. With acids it gives a slight effervescence and yields gelatinous silica. The aggregate of calamine and smithsonite on account of its peculiar porous structure is frequently spoken of as dry-bone.

118. TOURMALINE $R_9Al_3B_2(OH)_2Si_4O_{19}$

This mineral is a complex silicate, usually classified as a subsilicate, whose formula is not yet definitely established. The above formula, in which R stands for varying amounts of iron, magnesium, and the alkalies, seems to be the most generally accepted. Chemical composition determines the color of the tourmaline, thus iron tourmaline is black, magnesium tourmaline is brown, alkali tourmaline is red usually, but may also be blue or green, and occasionally practically colorless.

Tourmaline occurs in the Black Hills in the following ways:

a. As an accessory constituent in igneous rocks, as for example, the muscovite-tourmaline granite at Harney Peak.
b. In pegmatites.
c. In metamorphic rocks such as slates, phyllites, and schists.
d. In contact zones in granites and schists.
e. In quartz veins.
f. In small amounts in placers.

Tourmaline crystallizes in the hexagonal system and occurs in well defined crystals in all except the last mentioned. The crystals in the igneous and metamorphic rocks and in contact zones are usually small, the crystals in quartz veins are well defined, frequently an inch or two in diameter, while crystals a foot across have been recorded in pegmatite.

a. TOURMALINE IN IGNEOUS ROCKS. Tourmaline is present as an accessory mineral frequently in sufficient quantity to be noticeable to the eye, in the muscovite granite of Harney Peak. As a rule the tourmaline occurs in microscopic cyystals. These are in some cases fairly abundant and frequently attain a diameter of several millimeters. They are usually granular in appearance and black in color, and hence are frequently mistaken for cassiterite. In a few places a tourmaline dark blue in color and hence called indicolite occurs. In thin sections crystal outlines can frequently be detected. These usually show that the tourmaline occurs in minute stocky prism made up of three curving sides and terminated by rhombohedron faces.

In very minor amounts and in microscopic size, tourmaline also occurs in some of the monzonite and granite porphyries and related rocks in the Bear Lodge and Tinton district.

b. TOURMALINE IN PEGMATITES. In the pegmatites associated with the Harney Peak granite, tourmaline attains its maximum development. In these rocks it is exceedingly common and may be found in varying abundance anywhere in the southern Hills and also in the Nigger Hill district on the Wyoming line. There is a tendency in many pegmatites for the tourmaline crystals to stand with their long axes perpendicular to the walls. This has been frequently commented upon by various authors.

Well defined crystals are common. These are usually prismatic and frequently have splendid terminations. They occur in a series of forms best described separately:

Type 1. These are twelve sided prismatic forms, terminated by several rhombohedrons. The forms present are the trigonal prism a :αa :—a :αc (1010), and its complimentary form αa :a :—a :αc (0110), the hexagonal prism 2a :2a :—a :αc (1120), and the rhombohedrons a :αa :—a :c (1011) and αa :a :—a :2c (0221). These crystals are jet black in color and have a marked vitreous luster. There is no cleavage apparent, but all have poor conchoidal fracture. They are

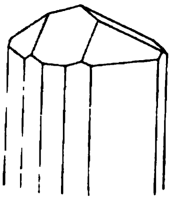


Fig. 65.

about equal to quartz in hardness and frequently a trifle harder.

Several of such crystals varying in diameter from 1⅛ to 2¾ inches are in the collection of the State School of Mines. All came from pegmatites near Custer.

Type 2. This type also consists of twelve sided prismatic forms made up of the same prisms as above, but terminated by a prominent basal pinacoid ∞a:∞a:∞a:c (0001), and by a very minor development of the rhombohedron ∞a:a:—a:2c (0221). Crystals from 1¼ to 4¾ inches in diameter represent this type in the State School of Mines collection.

Type 3. This type is made up of the same prisms as the two preceding, but the terminations are the rhombohedron a:∞a:—a:c (1011). These attain large size and are occasionally doubly terminated. One such in the State School of Mines collection shows the faces of the rhombohedron ∞a:a:—a:2c (0221). These crystals are the same in physical characteristics as the preceding types.

Type 4. (Presumably from pegmatite). These are a dense intergrowth of short prismatic crystals, black in color, showing a very prominent development of the trigonal prism a:∞a:—a:∞c (1010) and a minor development of the hexagonal prism 2a:2a:a:O (1120). These are terminated by the basal pinacoid ∞a:∞a:∞a:c (0001) and the rhombohedron a:∞a:—a:c (1011).

Type 5. Several of the larger crystals from the vicinity of Custer show distinct twinning visible by re-entrant angles both on the prism faces and on the terminal rhombohedron face. These crystals show the prism forms characteristic of type 3 and are terminated by the rhombohedrons a:∞a:—a:c (1011). The twins are simple penetration twins of two such individuals having their crystal axes parallel. An excellent twin of this character in the State School of Mines museum measures 5 inches in diameter.

Type 6. A well defined roughly three-sided crystal of black tourmaline from Keystone, about an inch in thickness, differ from the above types in showing splendidly developed oscillatory growth. This is well shown on the prism by three sets of prominent sharp and parallel ridges set well apart (⅛ to ¼ of an inch) parallel to C axis, perpendicular to the C axis, and at an angle of 38°, with the direction of the c axis respectively. These, judging from the interfacial angles, are evidently oscillatory combinations of the prisms a :αa :—a :αc (1010) and 2a :2a :—a :αc (1120) and the rhombohedrons a :αa :—a :c (1011) and αa :a :—a :2c (0221). The oscillatory combination of the two rhombohedrons gives rise to a deep concave termination on one end divided into several segments, each wedge shaped and marked by striations parallel to the main crystal outline.

Type 7. The above six types cover the form of those crystals occurring as essential minerals in the pegmatite. All are black in color and none except the last show the deep striations usually so characteristic of tourmaline. These crystals are usually broad and stocky. In some pegmatite, however, we get bright green radiating aggregates of tourmaline made up of indistinct slender prisms. These are evidently characterized by higher percentages of alkalis and by a consequent decrease in iron content in which the black tourmalines are high. The black tourmalines are also readily fusible, while the green are not. The prisms of the green tourmaline are deeply striated the long way. Such columnar aggregates occur as a simultaneous crystallization product with quartz and albite, and also frequently in small columnar bundles as inclusions in muscovite mica. In the latter case the crystals lie always with their long axis in the cleavage plane of the muscovite. The green color varies occasionally into pale sky blue shade. This is found in some tourmalines from Keystone.

Type 8. Under this I include a series of perfect, usually long prismatic tourmaline crystals of a very deep blue color. Fragments ⅛ of an inch thick are indigo blue by transmitted light. The crystals are striated nine sided prismatic forms, in some cases well terminated on both ends. The terminations are usually different, one end showing the rhombohedron a:∞a:—a:c (1011) and the basal pinacoid and the other end, the rhombohedron ∞a:a:—a:2c (0221). Occasionally such crystals are highly flattened between the cleavage plates of the mica. Some of these have no sharp terminations, but fray out into a number of fine shreds or minute prisms which project for some distance into the mica.

c. TOURMALINE IN METAMORPHIC ROCKS. Van Hise (18) first called attention to the tourmaline in the metamorphic rocks of the Black Hills. It is common only as a microscopic constituent of minor importance in the slates and phyllites, but becomes more important in the well crystallized schists.

Most of the tourmaline rich schists occur in the immediate vicinity of igneous rocks and owe their tourmaline enrichment to contributions from hot solutions during contact metamorphism.

d. TOURMALINE IN CONTACT ZONES. Wherever the pegmatites have cut the granites or the schists of the Harney Peak region they have produced contact zones greatly enriched in tourmaline. The crystals are usually small in size, frequently mere grains, but often short, moderately stocky prisms. Such occur in great profusion in schist near Glendale, Spokane, Custer, Keystone and elsewhere. The crystals are distinct hexagonal prisms without terminations. As a rule these rocks are rich in muscovite (white mica), but near Spokane the predominant mica is biotite (black).

e. TOURMALINE IN QUARTZ VEINS. Many of the quartz vein off-shoots of the pegmatites near Harney Peak contain some tourmaline. Three types of tourmaline occur in these veins, which are respectively dark brown, dark green, and jet black in color.

Type 1. The best development is reached in quartz veins northwest of Custer. Here we find dark brown deeply striated, curved and fractured prisms of tourmaline scattered in great profusion through a milky quartz. The prisms are curved and trigonal in cross-section and are running through the quartz in a very irregular reticulated manner. They attain a diameter of three-fourths of an inch, but are usually ¼ to ⅜ in thickness and four, five, and even six inches long. Along this distance they are usually broken into fragments and cemented by quartz. These quartz veins furnish some of the finest display specimens to be obtained in the Black Hills, and are so located that collections can easily be made.

Type 2. Near Custer well defined and smooth hexagonal crystals of tourmaline reach a diameter of 1 to 1½ inches. These are made up of the hexagonal prisms a :αa: —a :αc (1010) and2a :2a :—a :αc (1120) and the basal pinacoid αa :α :a :αa :c (0001).

Type 3. Dark green deeply striated columnar crystals also occur in quartz veins near Custer. These reach an extreme diameter of 1¾ inches and show no distinct terminations.

Tourmaline is also common in irregular masses, usually very fine grained in many quartz veins. Occasionally minute tourmaline needles are imbedded in iron oxides, and are frequently mistaken for wolframite or cassiterite. There is a specimen of tourmaline in the museum of the State School of Mines, which is quite different from the usual type. This is of dark brown color, is very finely fibrous, and has a beautiful silky luster. The specimen is from the vicinity of Rockerville and on account of its unusual structure and luster deserves special mention.

f. TOURMALINE IN PLACERS. Most of the gravels of the various streams near Harney Peak and also Nigger Hill will show small amounts of black tourmaline grains. These are easily mistaken for stream tin, but may be distinguished by the fact that they are much lighter in specific gravity and that minute fragments are translucent when held to the light, while cassiterite is not.

The tourmaline of the Hills varies in specific gravity as follows:

Black Tourmaline (Custer)........	3.02
Black Tourmaline (Keystone)......	3.00
Green Tourmaline (Custer).......	2.89
Brown Tourmaline (Custer)......	2.88
Blue Tourmaline (Keystone)......	3.17

Tourmaline is quite resistant to weathering and hence does not alter readily. In the vicinity of Custer, however, tourmaline has been altered to quite an extent into an aggregate of muscovite and quartz. These aggregates have formed pseudomorphs and preserves the long trigonal tapering form of the tourmaline crystals quite well. (See plate 21).

Tourmaline exhibits pyrœlectricity, that is, it becomes electrified after an application of heat. One end of the prismatic crystal has usually a positive charge, while the other end has a negative one. If a tourmaline crystal is heated for a few minutes it will show its electrification after cooling by picking up minute bits of paper, about the same way as a magnet picks up steel filings.

Tourmaline occurs black, blue, green, and brown in color in the Black Hills. It may be recognized by its extreme hardness, lack of cleavage, conchoidal fracture, strong vitreous luster, and by its three, six, nine or twelve-sided prismatic form which is usually striated the long way.

Clear, transparent varieties are suitable for gems and are quite valuable. None such have as yet been found in the Black Hills to the best knowledge of the writer.

119. STAUROLITE $H_2Fe_2Al_{10}Si_4O_{26}$

This mineral occurs in abundance in certain schists in the vicinity of Keystone. As a microscopic accessory mineral it is quite common in small amounts in many of the metamorphic rocks about Harney Peak, as was pointed out by Van Hise (19). It is well developed in rocks of the Holy Terror mine near Keystone. Here it occurs in a biotite schist, which shows a notable enrichment of staurolite. It is quite prominent in rocks north and south for several miles.

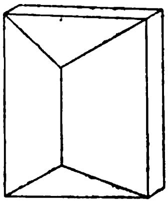


Fig. 65. Staurolite.

The staurolite occurs in well crystallized prismatic forms belonging to the orthhombic system. The common form is made up of the prism a:b:αc (110), the pinacoids αa:b:αc (010) and αa:αb:c (001), and the dome a:αb:c (101). Most crystals are less than three-fourths of an inch in length and one-half inch in width.

The color varies from reddish brown to a brownish black. The crystal faces are usually rough and have a greasy luster, but fractures show conchoidal surfaces and a vitreous luster. The hardness is about equal to that of quartz (7) and the specific gravity is 3.6. Small fragments are transluscent, and yellowish brown in color. The streak is colorless.

No specimens from other localities in the Black Hills are available for study.

120. SAPPHIRINE $Mg_5Al_{18}Si_2O_{27}$.

This mineral is mentioned by Todd (52) as occurring in the Bad Lands, having been identified by Mr. George F. Kunz. Judging from the description by Todd, it seems probable, however, that the name sapphirine was applied in the sense of a trade term to a blue colored true chalcedony, and was not used in the strict mineralogical sense.

The mineral "sapphirine" is probably unknown in the Black Hills.

121. NATROLITE $Na_2Al_2Si_3O_{10}$ 2 H_2O.

This hydrated alumino silicate of soda is a member of a group of minerals called zeolites. The name is compounded from the Greek, signifying boiling stones and alludes to the fact that when fused these minerals tend to froth and bubble. The group includes about thirty minerals, all hydrous silicates of soda, potash, lime and rarer, barium and strontium. The mineral Analcite discussed below is also a member of this group and differs only slightly from natrolite, its composition being $Na_2Al_2Si_4O_{12}2\ H_2O$.

Zeolites are minerals formed by the decomposition of feldspars. They are not the result of ordinary weathering, but are caused by alteration through hot solutions. In the Black Hills region zeolites are of no great importance, but are usually found as microscopic alteration products in rocks containing feldspathoids. Such are described by W. S. Tangier Smith (84) from the Bear Lodge mountains, and also occur in some of the nephelite bearing rocks of the northern Hills.

By optical tests natrolite has been identified. It occurs in minute radiating fibrous aggregates and as fibrous crusts coating feldspars crystals.

No natrolite occurs in large enough quantity to afford specimens.

122. ANALCITE $Na_2Al_2Si_4O_{12}2\ H_2O$.

This zeolite has been described as a microscopic constituent of phonolites and related igneous rocks from the Bear Lodge mountains, and the vicinity of Devils Tower. It occurs in isometric crystals, but only of minute size. Determinations were made by optical tests only.

[illegible] THE MICAS.

The micas are a group of orthosilicates of aluminum, carrying varying proportions of magnesium, iron, and of the alkalies. As a rule they contain minute amounts of water, and frequently fluorine. All micas crystallize in the monoclinic system, and although perfect crystals are very rare, they commonly occur in six-sided crystals. They are all very soft and possess such excellent basal cleavage that they may be split into exceedingly fine flakes which are transparent and very elastic. The colors vary, depending upon the composition, as follows: (Only those occurring in the Black Hills are listed).

1. Muscovite—potassium mica—colorless, yellow, or pale green.

2. Lepidolite—lithium mica—green, pink, or lilac.
3. Phlogopite—magnesium fluorine mica—brown.
4. Biotite—iron magnesium mica—black.

123. MUSCOVITE $HK_2Al_3(SiO_4)_3$.

This mica occurs in great abundance within the Black Hills area in the following ways:

1. As a mineral of minor importance in igneous rocks such as granite.
2. As crystals and masses often of great size in pegmatites.
3. As a constituent of varying importance in metamorphic rocks, such as schists and gneisses.
4. As an important constituent in certain contact zones, especially those in granite (greisen).
5. As a constituent of minor importance in detrital material, such as sand, gravel, sandstones, etc.
6. As a secondary mineral usually in minute flakes or fibers, formed by the decomposition of other silicates, especially feldspars.
7. In quartz veins.

Muscovite is colorless, yellowish, or green in color, has a hardness of 2 and is hence readily scratched by finger nail, and yields by cleavage exceedingly thin transparent and flexible sheets.

In the igneous rocks of the Black Hills muscovite is present as minute colorless flakes, which are usually less than 1/8 of an inch in diameter. Such occur in medium grained granite near Custer, accompanied by black mica (biotite). This also occurs in limited amounts in the granites of the Bear Lodge district. In the granite of Harney Peak the muscovite flakes attain a size up to several inches in diameter and may be found everywhere this granite is exposed.

Muscovite, in common with the other minerals of the Harney Peak district attains its best development in pegmatites. As a rule this mica occurs in large masses, called "books," which are irregularly distributed through quartz and feldspar. Frequently these books show much regularity, being arranged near one wall of the pegmatite. This is especially well shown in the New York mine, five miles west of Custer (65). These books frequently attain a diameter of two feet. Many of them yield large clear cleavage sheets when split. In thin sheets the mica is usually colorless—white when in masses. It carries as occasional inclusions needles and columnar bunches of green, blue and black tourmaline. Many of these books of mica have an additional cleavage in a direction steeply inclined to the first, which causes the mica to split into a series of long, narrow ribbon-like sheets. This is a defect in many micas, usually spoken of as a ruled structure. Other books tend to split up into wedge shaped sheets. Both of these defects impair the value of mica very seriously.

Mica is mined in the Black Hills at the present time in the vicinity of Custer and Keystone and is used to quite an extent in the manufacture of lubricants, as an insulator in electrical machinery, as ising glass for stove fronts, and many other purposes.

The most important mines producing mica at the present time are the New York and the White Spar mine near Custer. Other important mines are the Old Mike, the Climax, and the Firestone, all from the vicinity of Custer.

Occasional well defined crystals are found in these pegmatites, usually enclosed in quartz. Small crystals show a perfectly smooth hexagonal outline due to combinations of the monoclinic pyramid a:b:2c (221), and the pinacoid ∞a:b:∞c (010) in about equal proportion. These attain a size up to one or two inches in diameter, are usually flat tabular and show no terminations. Small muscovite crystals, made up of the pyramid a:b:2c (221) only and imbedded in quartz are known from the pegmatites near Keystone. Occasionally a series of such crystals occur in aggregates—nearly always as parallel growths (see plate). These are usually made up only of the monoclinic pyramid a:b:2c (221), and the basal pinacoid ∞a:∞b:c (001), although occasionally some show the pinacoid ∞a:b:∞c (010). Such aggregates are known from pegmatites near Custer.

Large masses of muscovite also occur in the pegmatites at Nigger Hill, Wyoming. In some pegmatites granular aggregates of yellowish green mica occur. The individual grains are usually less than one inch in diameter. In the Etta mine such aggregates carry small amounts of granular cassiterite. Blake (12) testing such mica flakes optically came to the conclusion that they are high in lithium. If not true lepiodolite, they at any rate represent a mica intermediate in composition between lepidolite and muscovite.

Muscovite occurs in many of the metamorphic rocks. It begins to appear as a microscopic constituent in some slates, but is more important in many of the schists about Harney Peak. Here it is frequently associated with garnet and tourmaline. The mica flakes vary decidedly in size, but are usually very small.

Wherever the pegmatites have cut through the Harney Peak granite they have produced zones locally enriched in quartz and muscovite. In these the flakes of mica reach an inch or more in diameter. These rocks usually contain much finely granular black tourmaline, and frequently small amounts of cassiterite.

Muscovite, although soft, is resistant to weathering, hence may be found in varying amounts in minute silvery scales in sands and gravels almost anywhere in the Black Hills. Under the microscope it can also be detected in some of the Algonkian quartzites.

Under the discussion of such minerals as feldspars, spodumene, tourmaline, nephelite and others, attention was called to the fact that they tended to decompose readily passing by alteration over into muscovite. Such terms as sericite, liebenerite, pinite are applied to this secondary muscovite. This differs quite decidedly from the ordinary, occurring usually as a mass of microscopic scales or fibers more or less impure from admixtures of clay or other decomposition products. These secondary muscovites may be found in minute amounts practically anywhere where any of the above named minerals occur. It is of some importance in larger masses as an alteration product of such minerals as leucite, tourmaline, and spodumene and has re-

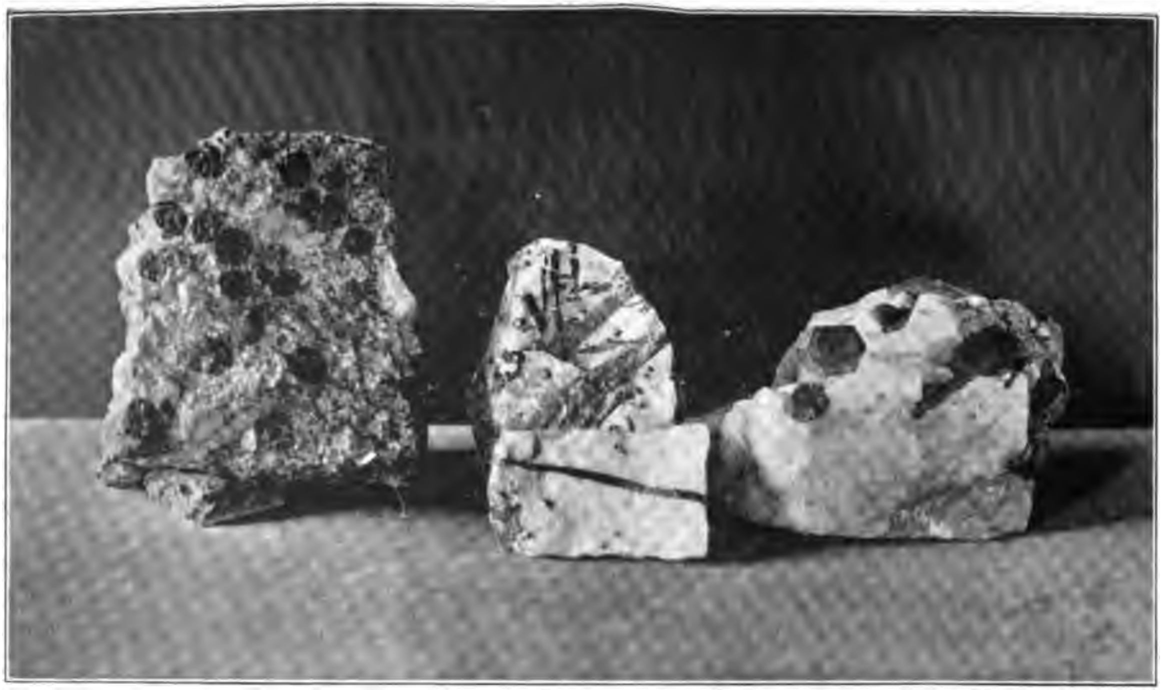


PLATE XXI:
Tourmaline, near Custer.
(⅓ natural size.)

Left, in Pegmatite.

Right, in Quartz Veins.

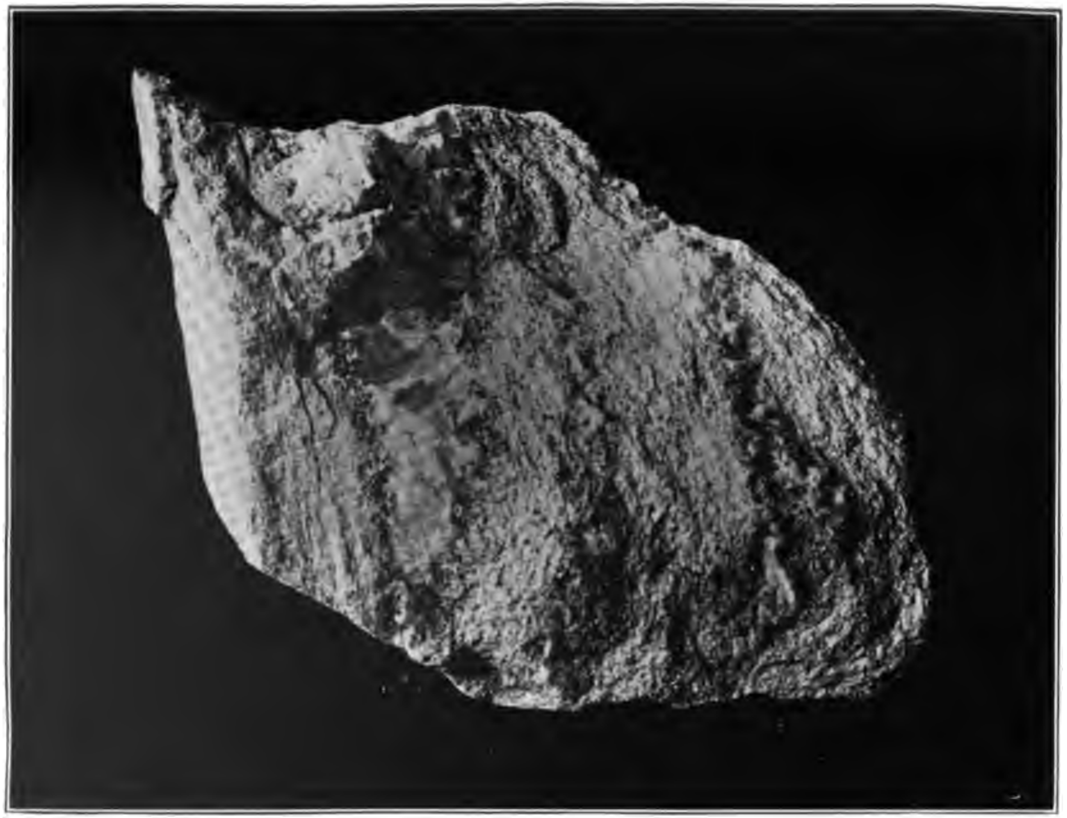


PLATE XXII: Tourmaline. Enriched Zones at borders of Pegmatite Stringer in Schist.
Harney Peak District.
(1-5 natural size.)

ceived special mention in the discussion of each of these minerals.

124. LEPIDOLITE LiK Al_3 (OHF) $(SiO_4)_3$.

This mineral differs from muscovite in composition by having varying amounts of lithium. Gradations between the two minerals occur and have been mentioned in the previous discussion.

Lepidolite occurs as equi-granular aggregates made up of lavender, lilac, pink or green individuals. These vary in size from minute grains to one-fourth of an inch in diameter. The grains of lepidolite have no crystal outline, cleave into thin elastic and transparent flakes as muscovite, are very soft and readily scratched by the finger nail, and have a specific gravity of 2.73.

Lepidolite is only known in the pegmatites of the Harney Peak district. The best lavender material comes from the Bob Ingersoll mine, four miles northwest of Keystone. It also occurs on the Beecher or Bond, the Christiansen and other claims near Custer. Near Keystone it is known in the Etta and Peerless and other claims. Green lepidolite occurs in the Peerless, the Bob Ingersoll, the Etta and other dikes near Keystone, and also in pegmatites north of Custer.

Lepidolite is used as a source of lithium salts, but none has been produced for this purpose in the Black Hills.

125. PHLOGOPITE $R_3Mg_3AlSiO_4))_3$.

In the above composition R stands for varying proportions of sodium, potassium, fluorine. When iron enters into the composition we get a gradation towards the black mica, biotite.

Phlogopite is only known from one locality in the Black Hills about 8 or 10 miles northwest of Custer. Here it occurs associated with actinolite in a white dolomitic marble. The phlogopite is disseminated in fair abundance through this rock in small golden brown flakes averaging one-fourth of an inch in diameter. These possess excellent basal cleavage yielding characteristic thin elastic and transparent lamellæ. They are very soft, but exceed the finger nail in hardness. Their luster is vitreous, but tends to approach the metallic. Color will distinguish it from the other micas.

126. BIOTITE $(HK)_2(MgFe)_2Al_2(SiO_4)_3$.

This mica is frequently spoken of as the magnesia-iron mica on account of its composition. It differs from the other micas in being dark brown or black in color, but possesses the same crystal form and the same perfect cleavage into elastic foliæ. The following occurrences of biotite are known in the Black Hills:

a. As a constituent usually of minor importance in igneous rocks.
b. As a rare constituent in pegmatites.
c. As an important constituent in metamorphic rocks.
d. As a minor constituent of sands and gravels.
e. In quartz veins.

Biotite is found in many igneous rocks in the Black Hills region. It occurs usually as small flakes of black color, which have a very bright submetallic or vitreous luster and a colorless streak. It is found in granites near Custer and Spokane and on Little Elk Creek, in the southern and central Hills; in various porphyries in many areas in the northern Hills, especially in andesites and diorites in Ruby Basin, and Deadwood Gulch; and in granite monozonite and syenite porphyries and related rocks in the Nigger Hill and Bear Lodge district.

In the igneous rocks the biotite flakes are always very small. In some pegmatites, however, they occasionally attain a diameter of 8 to 10 inches. In these it is very rare. It is known in small amounts in a few pegmatites near Sylvan Lake and also on the west base of Harney Peak. Such large masses are brown to black in color. By transmitted light their color is pale brown, reddish brown, or black, depending on the thickness of the specimen.

Biotite is a quite important constituent in some of the metamorphic rocks. It appears as microscopic grains in slates and phyllites, but attains maximum importance in certain gneisses and schists. Such are common about Harney Peak. In these the biotite flakes are usually small, and are arranged in parallel layers. Such schists occur near Keystone, Glendale, Hill City and Custer. They are usually dark in color and frequently carry such minerals as garnet, staurolite and tourmaline in addition.

Biotite is not easily decomposed, but under atmospheric action changes slowly over to chlorite. Frequently flakes of biotite are resistant enough to be accumulated with detrital material such as gravel, sand, and clay. It may be found in these practically anywhere in the vicinity of the Black Hills. These minute almost microscopic flakes assume a fine golden color and on account of their high shining luster in sunlight, are frequently mistaken for gold. A blow with a hammer will serve to distinguish them as they are brittle, while gold is malleable. They are also too light to be concentrated by planning. They may further be distinguished by their colorless streak.

127. OTTRELITE $H_2(FeMn)Al_2Si_2O_9$.

This mineral is very much like biotite in color and appearance. It occurs in minute flakes in little rounded disks in a dark colored schist about two miles west of Nahant.

No specimens are on hand for further description.

128. CHLORITE.

Under this general name we include a large group of hydrated secondary silicates of iron, magnesium, and aluminum, including such minerals as peninninite, prochlorite, ripidolite, and others. These are the important decomposition products resulting from the weathering of such minerals as hornblende, actinolite, augite and other iron and magnesium bearing silicates. These minerals are not completely understood and there is considerable confusion in the use of terms. The mineralogist Tschermak has lately proposed a two-fold classification of the chlorites into (a) Orthochlorites and (b) Leptochlorites. Under the orthochlorites he includes a series of minerals made up of isomorphous mixtures of the two compounds $Si_3Mg_3H_4O_9$ and Si $Al_2Mg_2H_4O_9$, while under leptochlorites he includes those minerals made up in part of these two substances and in part of some other magnesium aluminum silicate. Such chlorites as have been studied from the Black Hills seem to belong to the group of leptochlorites, although one at least has an unusual composition even for this group.

Chlorites are usually green in color, varying in shade from almost colorless to black. Rarer varieties are brown or yellow. They are common as a decomposition product of iron magnesium bearing silicates, hence occur frequently green, earthy, and impure, as a staining on such minerals. This is very common on most igneous and metamorphic rocks. Occasionally chlorites occur in thin dark green seams and veinlets—more especially in actinolite schists and in amphibolites. In some schists the chlorites become quite abundant. Thus they occur in the Homestake mine, where they are associated with quartz, arsenopyrite, pyrrhotite, calcite, cummingtonite, etc., and there they make up the main ore body. Such chlorite schists are known elsewhere in the Black Hills, as for example near Rochford and Mystic.

The chlorite is soft, has a greasy feel, and is hence incorrectly named talc by the miner.

Under the microscope we can see that much of the chlorite consists of minute flakes and some fibers, which are at times visible to the naked eye and which frequently show strong folding and contorted lamination.

Sharwood (103) cites the following analyses of chlorite from the Homestake mine:

	I.	II.	III.
SiO_2	25.35	26.21	24.20
Al_2O_3	25.23	23.92	20.90
Fe_2O_3	....	1.89	4.27
FeO	32.76	30.63	32.34
MgO	....	8.05	9.42
CaO	trace	.40	trace
Water	9.60	8.80	8.39

Analyses I and II are of dark green chlorite, which is foliated and more or less contorted, analysis III is of "minute scales or plates of a distinctly lighter green color." These analyses lead Sharwood to suggest the formula MgO

2FeO Al_2O_3 2 H_2O 2 SiO_2. This seems to differ from other chlorites in being high in MgO and FeO and low in H_2O.

Analysis I is incomplete, but analysis II may be readily recalculated into leptochlorite made up of mixtures of the following moleculas in the proportion indicated:

96 (3 MgO 2 H_2O 2 SiO_2).

99 (2 MgO Al_2O_3 2 H_2O SiO_2)

146 (MgO $Al_2O_3H_2O$ SiO_2)

The CaO and FeO and the Fe_2O_3 replace the MgO and the Al_2O_3 molecule respectively. This would leave us 0.85% short in H_2O content, which could be neglected. Such a leptochlorite would be a member of group III a of Hintze's classification and would be closely related to the leptochlorite, aphrosiderite.

Analysis III gives more difficulty in recalculation, but if as Hintze advises the water percentage be neglected (see foot note 3, page 685, Handbuch der Mineralogie) this can be readily calculated into the following proportion:

85 (3 MgO 2 H_2O 2 SiO_2).

207 (2 MgO Al_2O_3 2 H_2O SiO_2).

25 (MgO Al_2O_3 2 H_2O SiO_2).

Which would make this mineral a leptochlorite belonging to Group I of Hintze's classification. This interpretation leaves us short 2.97% H_2O. This loss would appear to be too large to be accounted for by partial dessication and hence it is probable that some molecule analogous to the above; but low in water enters in, which has not been recognized by Hintze. The addition of a molecule 2 MgO Al_2O_3 H_2O SiO_2 to the above replacing 164 of the 2 MgO Al_2O_3 2 H_2O SiO_2 molecules would check with analytical figures, and since these are reliable would afford the more satisfactory explanation.

129. SERPENTINE H_4 Mg_3 Si_2O_9.

This mineral is also a common decomposition and weathering product in igneous rocks. It usually occurs in minor amounts only in this way in the Black Hills and is quite impure due to admixtures of other secondary minerals. Microscopic examinations are usually necessary to prove its presence.

Serpentine is also a quite important constituent of marble northeast and northwest of Custer, occurring in greater or less amounts as disseminated grains and irregular masses. The color of the serpentine varies from yellow to green. Sulphur or straw yellow, yellowish brown, clear leek green, light yellowish green, or very dark green are the common shades. Usually the serpentine is quite evenly scattered through the rock, causing uniform mottling with green or yellow on the pure white marble. This rock is capable of taking a high polish and yields strikingly handsome specimens well suited for decorative work. Such marbles are frequently known as ophicalcites.

Dark green masses of serpentine with a beautiful waxy luster, a hardness of about 4.5 and a specific gravity of 2.6 occur in the Minnie May mine.

130. TALC $H_2Mg_3(SiO_3)_4$.

This mineral is also a secondary mineral formed by the alteration of magnesium bearing silicates. As an impure decomposition product it is quite common in schists and amphibolites in which case it is usually formed by the alteration of actinolite. It is usually so impure and in so small amounts that it can be identified with certainty only under the microscope.

Larger and purer masses of talc occur in the Harney Peak district in some pegmatites as for example, one mile west of Hayward and also on Squaw Creek, and on Box Elder Creek near Jim Creek.

The talc found on Squaw creek is a massive, very fine grained, and compact variety known as French chalk or steatite. It is pure white in color with a pale greenish tinge. The talc near Hayward varies from white to a yellowing or greenish shade and in places is stained deep brown by iron oxides. Although it is very slightly foliated, it is dense and compact.

The talc has a very greasy feel, is so soft as to be readily scratched by the finger nail and is light (2.57 in specific gravity).

131. GLAUCONITE.

This mineral is a hydrous silicate of iron and potassium and is supposed to have been formed by direct precipitation from ocean water often through the decomposing organic material of dead animals such as molluscs and brachiopods. According to Murray and Renard.*

"The shell is first filled with fine silt or mud, upon which the organic matter of the dead animal can act. Through intervention of the sulphates contained in the sea water, the iron of the mud is converted into sulphide, which oxidizes later to ferric hydroxide. At the same time alumina is removed from the sediments by solutions and colloidal silica is liberated. The latter reacts upon the ferric hydroxide in presence of potassium salts extracted from adjacent minerals, and so glauconite is produced."

As has been shown by others, glauconite may also form in rocks subsequent to their consolidation. Minerals practically the same in composition and probably identical occur as decomposition products of ferromagnesian minerals such as augite.

Best analyses seem to indicate that pure glauconite has the formula $FeK(SiO_3)_2$ plus water, in which the iron is in the ferric state, and in which iron may be partly replaced by aluminum, and potassium by other bases.**

Glauconite is especially common as a cementing material in limestone conglomerates and in the shale beds of the Deadwood formation. Here it occurs as a finely granular bright to bluish green to almost black mineral. It is frequently abundant, giving whole layers a decidedly green appearance. It weathers out readily forming pockets and streaks of bright green granular sand. The streak of the glauconite is pale green, it is very soft, and although it does not occur in crystals, the small grains show fair cleavage in one direction. It is very low in specific gravity. The Black

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*Clarke, F. W. Bull. 491, p. 492, U. S. Geological Survey.

**Clarke—Loc. cit.

Hills glauconite is practically insoluble in acid, but may readily be fused into a magnetic globule.

It occurs in varying amounts wherever the limestone and shale layers of the Deadwood formation are exposed.

According to Irving (74) it differs from true glauconite in being fairly high in alumina content.

132. SAPONITE OR BENTONITE.

This mineral (?) is reported by C. W. Knight (33) as occurring in Crook county, Wyoming, west of Sundance. Here it makes up a bank of clay interbedded with cretaceous rocks.

Judging from descriptions, it is the same material which subsequently was called bentonite by Darton (84). It seems to be a clay high in alkalis and alkali earths and it is more probably an aggregate of several minerals and not a distinct mineral species.

The following description is by N. H. Darton (84): "This mineral is a hydrous silicate of alumina with some other components in small proportions, and is valuable on account of its high absorbent qualities, as it has the capacity of absorbing three times its weight of water. It occurs in considerable abundance in the Newcastle quadrangle and has been mined to some extent three-fourths of a mile east of Pedro switch, a mile west of that switch, and at a point 3½ miles northwest of Osage, on the east side of the railroad track. The material is light-gray, fine-textured, soft, massive stone, but locally it occurs as a light powdered substance resembling white corn meal, in beds lying between thin layers of reddish-brown concretionary material. Near Pedro it is 12 feet thick and occurs in the steep-dipping transition beds at the top of the Niobrara formation. Near Osage the bed is about 4 feet thick and occurs in the Graneros shale, the dips of which are so low that the deposit is exposed over a considerable area. The mineral has been used with success in the manufacture of soap, but it has proved most valuable as a packing for a special kind of horseshoe, and as a diluent for certain powerful drugs sold in powdered form."

The following analyses are both by the Wyoming State School of Mines:

SiO_2	63.25	61.08
Al_2O_3	12.63	17.12
Fe_2O_3	3.70	3.17
MgO	3.97	1.82
CaO	4.12	2.69
K_2O	3.55	....
Na_2O	....	0.20
H_2O	6.91	12.10
MnO	....	trace
H_2SO_4	1.58	0.88

133. KAOLINITE $H_4Al_2Si_2O_9$.

This mineral, also frequently spoken of as china clay or as kaolin, is the chief constituent of clays, and hence also of such rocks as shale and slate. It is the most common alteration product of feldspars, especially the orthoclases, and is produced by the ordinary processes of weathering. It is of universal occurrence, but as pure mineral is rare in the Black Hills, and when so occurring is only in small amounts. Thus any thin section of the igneous or metamorphic rocks of the Black Hills will show the presence of kaolinite. In the Harney Peak district the exposed portions of pegmatites decompose to a clayey siliceous substance which is predominantly kaolin. This is usually white, very soft, somewhat greasy to the touch, and very plastic when wet. If it occurs pure and in fair amounts it is quite valuable and used especially in the manufacture of china and porcelain.

The plasticity of clays is thought to be due to the presence of kaolinite. Here this mineral, although usually making up the greater part of the rock, is mixed with other clay minerals and with finely comminuted quartz, feldspar, limonite, and carbonates of calcium and magnesia. Small quantities of kaolinite of fair quality occur northeast of Custer.

In many of the gold mines of the Ruby basin district there occurs a very peculiar clay as distinct thin layers between the strata of the Deadwood formation. These layers are often only a few inches in thickness, but in one case are said to attain a thickness of one foot. This is usually white in color, but grades into a yellowish and also a bluish shade, [illegible] mineral.

[illegible] in rocks [illegible] of Bear Lodge [illegible] Sherman [illegible]

[illegible] Bear Lodge district [illegible] and vary in color [illegible] pale green or pale blue. [illegible] cleavage and a [illegible] when pure adheres [illegible] The specimens are frequently quite [illegible] mixed with impure copper [illegible] distinguished by [illegible]—to the min- [illegible] effervesce vigorously while on [illegible] remain inactive.

[illegible] TITANITE $CaTiSiO_5$

This mineral is only known as a microscopic constituent of several of the igneous rocks in the Black Hills and has not yet been found in sufficient size to yield a specimen. It occurs in some porphyries in the northern Hills, in gneissic granite on Little Elk creek, in granite near Custer, and the Bear Lodge district, and in rare crystals in the pegmatite of Harney Peak.

GROUP OF OXYGEN SALTS.

c. Niobates, Tantalates.

Under this group we include those rare minerals that are salts of niobic and tantalic acid. The minerals columbite and tantalite—the niobate and tantalate of iron respectively—are the only representatives of this group known in the Black Hills. These two minerals are so similar and occur so frequently as isomorphous mixtures that they are best discussed together.

137a—137b. COLUMBITE—TANTALITE.

In 1884 Prof. W. P. Blake (6) recorded the first discovery of columbite in the Etta and the Bob Ingersoll claims in the northern Hills. As of especial interest he briefly described one great mass over 2,000 pounds in weight. Schæffer briefly described tantalite from the Black Hills. Subsequently both tantalite and columbite were found in the Nigger Hill district.

Columbite seems to favor tin deposits and is quite frequently associated with cassiterite and more especially so in pegmatites and greisen. Columbite usually occurs as minute to coarse grains, bladed and irregular aggregates, crystalline masses, or scattered roughly faced and distorted bladed crystals which are frequently deeply striated. The crystals belong to the orthorhombic system. Blake (27) and Headden (24) especially have been instrumental in working out the forms represented and the following data on crystals is compiled mostly from their writings.

The largest mass ever found, as already mentioned, was estimated to exceed 2,000 pounds in weight. It was imbedded in quartz and penetrated this in a series of thin tabular crystals with brilliant prismatic and terminal planes. Finest individual crystals come from the Etta Mine where they occur in pegmatites, especially as inclusions in albite. Most of the crystals are flat tabular and frequently quite complex, especially if small. Good crystals occur also in the Bob Ingersoll, the Hugo, the Advance, the Peerless, the Sarah, and the First Find claim—all near

Keystone, and in the Yolo and Centennial claims in the Nigger Hill district. The crystals from the Etta are usually terminated by many bevelling planes, while those from the Bob Ingersoll are characterized by simple acute wedge-like terminations. The crystals from the Advance claim are usually prismatic.

The following forms have been reported:

Pyramids—		
(1)	a :b :b	(111)
(2)	3a :3b :c	(113)
(3)	3a :b :c	(133)
(4)	2a :b :2c	(121)
(5)	6a :b :2c	(163)
(6)	6a :b :3c	(162)
(7)	6a :2b :3c	(132)
(8)	2a :b :c	(122)
(9)	3a :b :3c	(131)
Prisms—		
(10)	a :b :αc	(110)
(11)	3a :5b :αc	(530)
(12)	3a :7b :αc	(730)
Domes—		
(14)	3a :αb :c	(103)
(15)	2a :αb :c	(102)
(16)	αa :b :3c	(031)
(17)	αa :b :6c	(061)
(18)	a :αb :c	(101)
Pinacoids—		
(19)	αa :αb :c	(001)
(20)	αa :b :αc	(010)
(21)	a :αb :αc	(100)

The color is usually grayish black or dull black. The luster varies—on the macro-pinacoid (No. 20 above) it is bright metallic, on other faces less shiny, and on the basal pinacoid (No. 19) quite dull. The streak varies from a dark brown to a grayish black. The hardness is from 6 to 6.5 and the mineral may only be scratched with great difficulty by a knife. Columbite is quite brittle, has very poor cleavage parallel to the pinacoids No. 20 and No. 21. This is absent on many specimens. All specimens show a somewhat indistinct conchoidal fracture. The specific gravity varies decidedly, depending on the relative proportion of niobium (Cb) and tantalum (Ta) in the mineral. Black Hills specimens vary in specific gravity from 5.38 to 8.20. The latter being practically pure tantalite.

The following tabulation of analyses show the ranges of composition, the locality of occurrence being indicated, as is also the source, by a number referring to the appended bibliography.

		S. G.	Nb_2O_5	Ta_2O_5	SnO_2	FeO	MnO	CaO	Total	Reference
1	Etta	5.890	54.09	18.20	0.10	11.21	7.07	0.21	100.88	(23)
2	Etta	6.181	47.07	34.04	0.30	11.15	7.80	...	100.34	do
3	Etta	6.245	46.59	35.14	0.18	7.44	10.94	...	100.29	do
4	Etta	6.376	40.37	41.14	0.13	8.28	9.09	0.88*	99.89	do
5	Etta	6.515	39.94	42.96	tr.	8.59	8.82	...	100.31	do
6	Etta	6.612	35.11	47.11	0.35	8.37	9.26	...	100.20	do
7	Etta	6.707	31.31	52.49	0.09	6.10	10.71	...	100.70	do
8	Etta	6.750	29.78	53.23	0.13	6.11	10.40	...	99.70	do
9	Peerless	6.373	37.29	44.87	0.09	6.87	11.02	...	100.14	do
10	Peerless	6.445	40.28	42.09	0.19	6.70	11.23	...	100.49	do
11	Bob Ingersoll	5.901	57.32	23.43	0.09	6.29	13.55	...	100.68	do
12	Bob Ingersoll	5.906	54.64	25.62	0.15	6.80	12.61	...	99.82	(81)
13	Sarah M	5.804	61.72	10.93	0.25	11.21	8.67	...	100.79	(23)
14	(?)	6.565	40.07	42.92	0.20	9.73	7.24	...	100.16	do
15	Mallory Gulch	6.232	41.69	40.19	0.11	9.88	8.70	...	100.57	do
16	do	6.469	37.28	44.48	0.16	9.29	8.68	...	99.89	do
17	Yolo	6.592	24.40	57.60	0.41	14.46	2.55	0.73	100.15	do
18	Elk Creek ..	6.170	47.22	34.27	0.32	1.89	16.25	...	99.95	do
19	Cora (?)....	6.393	37.91	44.55	0.09	6.70	11.05	tr.	100.30	do
20	Grizzly Bear Gulch	7.773	6.23	78.20	0.68	14.00	0.81	...	99.92	do
21	do	7.789	6.24	78.35	0.58	14.05	1.14	...	100.36	do
22	do	8.200	3.57	82.23	0.32	12.67	1.33	...	100.12	do
23	Etta (?).....	7.72	...	79.01	0.39	8.33	12.13	...	99.86	(7)
24	Advance	6.170	47.22	34.27	0.32	1.89	16.25	...	99.98	(23)
25	do	....	45.66	35.53	0.38	2.29	16.25	...	100.00	do

Analyses 1 to 8 show the variation in composition of the specimens from one locality—the Etta Mine—near Keystone and also show the consequent variation in the specific gravity. Analyses 17, 21, 22 and 23 are of tantalite; while analyses 18, 24 and 25 are also noticeable on account of the high amount of manganese which replaces the iron. Such are usually known as manganotantalite. Another generalization which seems to be nearly always true is that with an increase in the tantalum content there is also an increase in the percentage of manganese present.

The minerals associated with columbite have already received full mention in the discussion of cassiterite, where the means of distinguishing it from the latter mineral are also given. As a rule columbite seems to favor greisen-like developments of granite and the albite pegmatites where it is usually enclosed in the albite feldspar. A large mass of columbite in the Etta mine was full of cavities filled with a beautiful yellow powder in pellets and pill-like balls, which proved to be a hydrous uranium oxide (6) probably uraconite.

No columbite or tantalite has been mined in the Black Hills on a commercial scale, but quite an amount of material has been sold to mineral dealers. Tantalum is used to a limited extent for wires in incandescent lamps. The total amount so used in the world does probably not exceed several hundred pounds.

Both tantalite and columbite are found in placers, as for example on Elk creek and in Grizzly Bear Gulch and Mallory Gulch in the Nigger Hill district. The most prominent pegmatites carrying columbite are on the Sarah, the Advance, the Etta, the Hugo, the Peerless, and the Bob Ingersoll claims in the Harney Peak district, and on the Yogo, Uncle Sam and Centennial claims at Nigger Hill.

GROUP OF OXYGEN SALTS.

d. Phosphates, arsenates and vanadates. Under this group we include a series of minerals that are salts of phosphoric, arsenic or vanadic acid. They are all rare minerals.

138. MONAZITE (Ce La Di) PO_4.

This phosphate of the rare earth's cerium, lanthanum, and didimium, usually carries small amounts of thorium as an inclusion. It is reported by Mr. Scott (private communication) as occurring in small amounts in certain placers on Spring creek, and on Newtons Fork, and several of their tributaries. No specimens are on hand for description.

139. PURPURITE (Fe Mn) $_2 P_2O_8 4 H_2O$.

This iron manganese phosphate was first described by Schaller (92) in specimens from Hill City furnished him by J. N. Smith.

Here it occurs as a decomposition product on triphylite and triplite lithium-iron-manganese phosphates, which also occur in other pegmatites near Harney Peak. The purpurite occurs especially along the cleavage cracks of the above minerals and is present only in small amounts. It has a dark reddish to purple color which gives it the name, and a deep rose to purple colored streak. The mineral is 4 to 4.5 in hardness and has a specific gravity of 3.40 (92). It possesses good cleavage at right angles, which is probably pinacoidal.

The following analysis is by Schaller (92):

P_2O_5	43.45%
Fe_2O_3	38.36
Mn_2O_3	12.08
CaO	1.37
H_2O	4.82
Insoluble	.19
MgO Na_2O LiO_2	trace
	100.27

The above analysis shows that the purpurite is a mixture of approximately 76% $Fe_2P_2O_84H_2O$ and 24% $Mn_2P_2O_84H_2O$.

In small amounts it occurs wherever triplite or triphylite occurs in the pegmatite dikes near Keystone or Hill City, as for example, in the Etta, Bob Ingersoll, Tin Queen, Everly, Margaret, Blue Tin, and other claims.

140. TRIPHYLITE—SODA-TRIPHYLITE.

This mineral is usually considered an isomorphous mix-

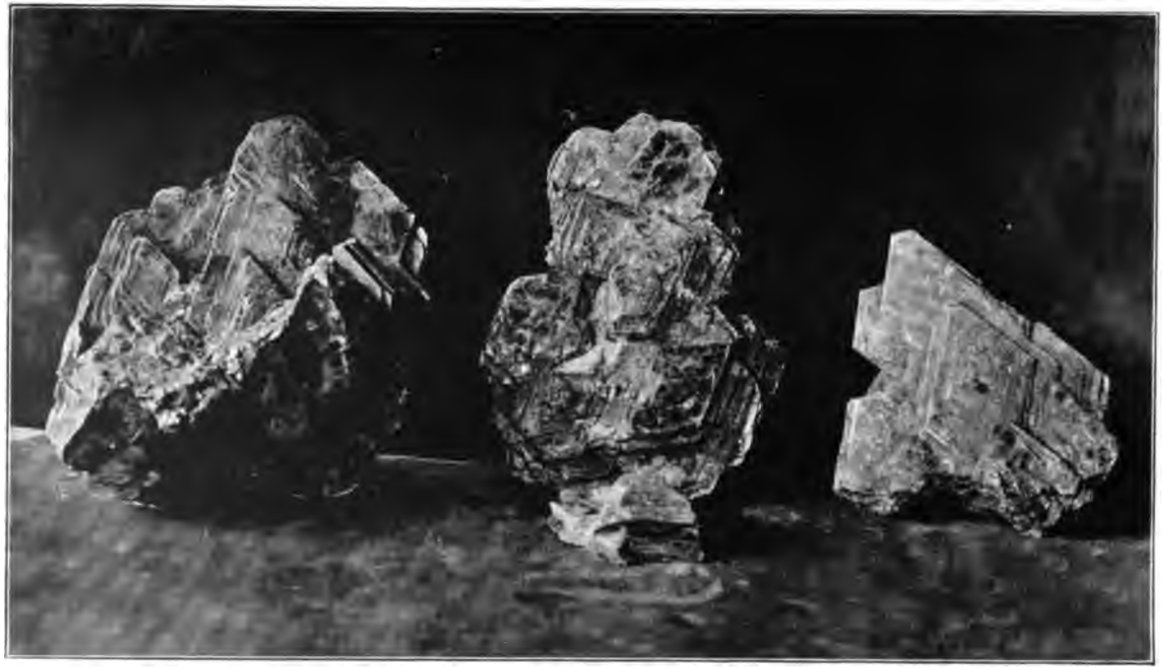


PLATE XXIII: Muscovite.
Crystals from vicinity of Custer.
(⅓ natural size.)

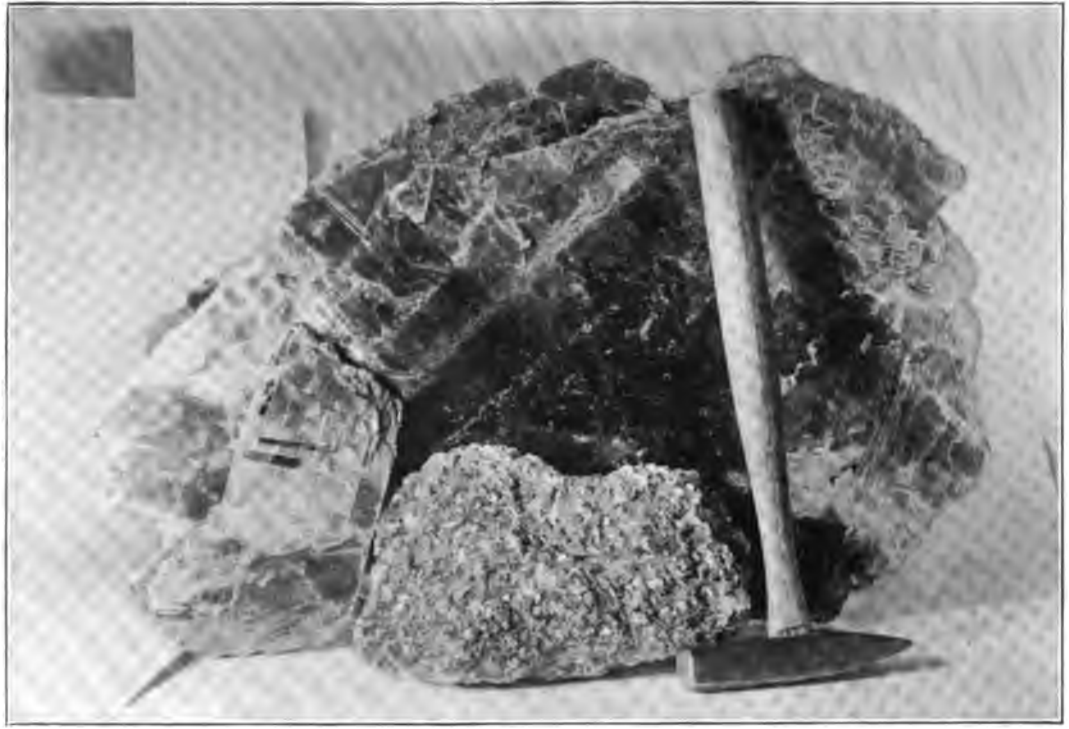


PLATE XXIV: Muscovite.
Large sheet from Custer, others from Keystone.

ture of Li_3PO_4 and $(FeMn)\ _3P_2O_8$ in about the ratio of 1:1. The Black Hills mineral first analyzed by Headden (25) is characterized by very low percentages of lithia, which is replaced by fair amounts of soda and minor amounts of potash. The formula of the Black Hills mineral may be expressed as $m(NaK)_3PO_4\ n\ (FeMn)_3P_2O_8$. It is desirable to distinguish this from the true triphylite and the writer would suggest the name soda triphylite on account of the high soda content. This seems to represent a gradation towards natrophylite, the soda manganese phosphate $(NaMnPO_4)$.

This mineral is well described in the following words by Headden (24):

"The mineral ——— is, in the mass, dark green, in thin splinters it is translucent to transparent and is a light yellowish green; it fuses easily on the edges of thin pieces in the flame of a candle to a dark brown megnetic globule and colors the blowpipe flame a faint yellow. It has a hardness of about 5, a specific gravity of 3.612; cleavage in two directions, in one it is perfect, in the other it is quite imperfect and the directions are not at right angles to each other. The luster is vitreous and the fracture uneven to small conchoidal; streak and powder very light green, almost white. When exposed to the atmosphere for a short time it darkens externally due to oxidation. The freshest material was taken for analyses which gave the following results:"

	I.	II.
P_2O_5	38.52%	38.76%
FeO	25.29	24.82
MnO	15.45	15.64
Ca0	5.42	5.64
MgO	1.56	1.44
Na_2O	7.46	...
K_2O	2.00	...
Li_2O	...	.28
F	.69	..
Ignition loss	.73	..
Gangue	2.49	2.44

The above material came from the Nickel Plate tin mine, in Pennington County.

Clove brown varieties of triphylite, which have a strong submetallic luster and which are frequently coated with minute purple or rose red crystals of purpurite, or with scales of submetallic heterosite of iridescent green and violet color, occur in several pegmatites near Hill City. Triphylite has been found in the Louise and Tin Queen claims near Oreville, and in the Etta claims near Keystone.

141. LITHIOPHYLITE Li(Mn Fe) PO_4.

When lithia becomes a prominent constituent in the formula given for triphylite above, the name lithiophylite is usually applied. This occurs in cleavable nodules and masses often 50 and more pounds in weight, irregular disseminated in many of the coarser feldspathic pegmatites of the Harney Peak district. It is a brown to brownish black color, has a submetallic or resinous to dull luster, and a clove brown streak. The hardness is the same as triphylite (5) and the specific gravity is 3.45. It alters readily to purpurite (Fe Mn) Po_42H_2O.

It is mined as a source of lithia, the Reinbold Metallurgical Co. having mined about 100 tons at various times at the Dyke lode near Bismuth and the Lost Bonanza near Keystone. The Hugo and Peerless Mines near Keystone being worked at present. To distinguish between triphylite and lithiophylite a quantitative determination of Li_2O is necessary. Although no quantitative analyses are available, most of the lithiophylite shows fair amounts of fluorine and hydroxyl present. Judging from a number of qualitative tests, most of the Black Hills lithiophylite is a transition to triplite.

142. HETEROSITE.

The so-called heterosite is an alteration product of the soda triphylite not well understood, and probably not to be regarded as a distinct mineral, although usually listed as such in the articles on Black Hills mineralogy.

It appears as a coating usually of submetallic luster with an iridescent violet and green color on exposed surfaces of soda triphylite.

THE APATITE GROUP.

Under this group we include the following Black Hills minerals, which are quite similar in composition and have practically identical crystalline form:

Apatite $3\ Ca_3P_2O_8 + Ca(Cl\ F)_2$
Pyromorphite $3\ Pb_3P_2O_8 + Pb\ Cl_2$
Vanadinite $3\ Pb_3V_2O_8 + Pb\ Cl_2$

143. APATITE $3\ Ca_3P_2O_8 + Ca\ (F\ Cl)_2$.

This mineral is quite widespread in occurrence in the Black Hills region and is known as a constituent of pegmatites where it occurs sometimes in masses of large size, as a minor accessory constituent in many igneous rocks and in certain metamorphic rocks, and as an occasional grain in sands and placers.

In igneous rocks and in metamorphic rocks the apatite occurs as minute prismatic hexagonal crystals which are only apparent under the petrographic microscope. Thus apatite crystals are found in the granitic rocks and the mica schists of the Harney Peak district, in many of the irruptive rocks, usually known as porphyries, in the northern Hills, and in the granitic igneous rocks of the Bear Lodge and Nigger Hill districts.

The finest and largest masses of this mineral are found in pegmatite, especially those near Keystone and Custer. The common color of the apatite masses is deep blue, although a pale bluish green colored apatite is also common in certain pegmatites, as for example in the Tin Queen claim east of Oreville. The blue apatite which has been reported in masses up to a foot in diameter, has a hardness of 5, a specific gravity of 3.05, a vitreous to weakly greasy luster, and a colorless streak. It is quite common in the pegmatites of the Louise, the Tin Queen, the Peerless, the Etta, the Christiansen (now the Hugo), the Brown Tin, the Blue Tin and other claims near Keystone and in the White Spar mine near Custer and in pegmatites along French creek.

Crystals of apatite are rare, but are reported by Scott (44) from the Brown Tin and the Blue Tin prospects near

Harney City.

Fine lavender to violet colored crystals of apatite were collected by Mr. Alfred Alder, a student at the School of Mines, from a pegmatite slightly north of Glendale. These are usually less than 1-3 inch in length and 1/4 inch in thickness. The crystals are quite similar. The following forms were observed on a rather perfect one:

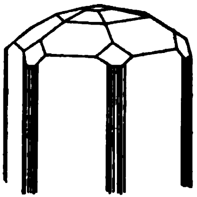


Fig. 68

Pyramids (First order):
1. (a: α a: —a: c)
2. (2a: α a: —2a: c)

Pyramids (Second order):
3. (2a: 2a: —a: 2c))

Prisms:
4. (a : α a: —a : α c)
5. (2a: 2a : —a: α c)

Basal Pinacroid:
6. (α a: α a: α a: c)

In the pegmatite of the Hugo Mine near Keystone there occurs a handsome fibrous variety of apatite. This varies in color from sea green into violet and even colorless and occurs in long slender prismatic aggregates imbedded in quartz and associated with small amounts of fluorite.

Apatite is quite resistant to weathering and in minute grains may be looked for in placers and stream sands practically anywhere.

None of the Black Hills material has been produced commercially.

144. PYRROMORPHITE $3 Pb_3 P_2O_8 + Pb Cl_2$.

In many of the lead deposits of the Hills, as for example near Carbonate, Galena, Spokane, etc., this lead phosphate occurs, usually above the ground water level as a coating of distinct small hexagonal crystals on the altering galena, associated with cerussite ($PbCO_3$), anglesite ($PbSO_4$), vanadinite ($3 Pb_3V_2O_8 + PbCl_2$) and iron oxides. Occasionally pyromorphite occurs also in irregular masses of fair size covered on the surface with small crystals. The

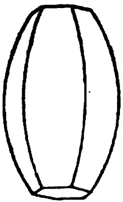


Fig. 69.

crystals are distinctly hexagonal in cross section and slender prismatic. Many are barrel-shaped slightly rounded and tapering the long way, and are terminated by small basal planes. None of these on the specimens in the State School of Mines collection exceed a diameter of ¼ of an inch or a length of about one-half inch. Other crystals tend to taper down to fine points on both ends, due to a slight curvature of the prism planes along the vertical axis, and suggest a very slender hexagonal bipyramid. Frequently these crystals are so slenderly developed as to form felt-like or hair-like mats or crusts. All specimens brought to the attention of the writer are light brown in color, and have a decidedly brilliant resinous luster. Cleavage is not apparent, but there is a weak and small conchoidal fracture. The specific gravity as determined (probably a little low) is 6.62, the hardness is 3.5. The streak is white.

Pyromorphite is very readily fusible into a globule, which on cooling assumes a crystalline form. The name (from the Greek for fire and form) alludes to this fact.

Pyromorphite is easily confused with the vanadinite with which it is associated. The latter mineral, however, is not quite as hard and may be scratched by a crystal or cleavage fragment of clear calcite which may be employed as a quick test for distinction.

The finest pyromorphite crystals and fibrous crusts come from Iron Hill in the Carbonate district.

145. VANADINITE $3\ Pb_3V_2O_8 + Pb\ Cl_2$.

This vanadate of lead, although somewhat rarer than pyromorphite, is usually associated with this mineral and in common with the latter is a secondary mineral formed by the alteration of galena. It occurs in small and slender prismatic crystals often hair-like in fineness, which have a light brown color and a more vitreous luster on the faces than the pyromorphite exhibits. On fractured surfaces the luster is resinous. The crystals are very sharp, simple hex-

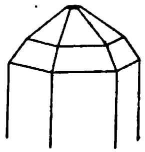


Fig. 70.

agonal prisms. Many of the smaller ones are terminated on the free end by two hexagonal biramids (a :αa :—a :c) (1011) and (a :αa :—a :2c) (2021) and a minute basal pinacoid. The slender prisms of vanadinite lack the rounding effect parallel to the c axis so well shown by pyromorphite, or have it only very slightly developed.

The vanadinite crystals show no cleavage, but a poor and flat conchoidal fracture. The hardness is 2¾ and the specific gravity is 6.76. The crystals are clearer than the pyromorphite and are a light reddish amber color by transmitted light.

It occurs sparingly in the upper part of lead deposits near Galena, Carbonate and Spokane. Good crystals occur sparingly at Iron Hill near Spokane.

146. TRIPLITE $(FeMn)_3P_2O_8(FeMn)F_2$.

This mineral occurs in imperfectly crystalline masses of brown to black color in some pegmatites near Harney Peak, as for example on the Etta, Bob Ingersoll, and Tin Queen claims. Here it is usually associated with triphylite, griphite, purpurite and heterosite.

The irregular masses of triplite exhibit cleavages about at 90°, one of which is perfect, while the other is indistinct and uneven. The luster is submetallic and inclined to resinous. The streak varies from yellowish gray to dark brown. By transmitted light this mineral is brown in color and much less translucent than triphylite. The hardness is about 5.5, the mineral being scratched with difficulty by a knife. The specific gravity is 3.52. It is easily fusible, yielding a magnetic globule.

L. G. Eakins (in bulletin 60, U. S. Geological Survey, p. 135) gives the following analysis of triplite from a "tin mine near Rapid City, S. D."

SiO_2	0.43%
Al_2O_3	8.74
Fe_2O_3	2.36
FeO	1.97
MnO	29.13
CaO	6.72
MgO	trace
K_2O	trace
Na_2O	5.25
LiO	0.13
P_2O_5	39.68
H_2O	3.67
F	2.35
Cl	0.25
Co_2	0.26
	100.94

It is very probable that this analysis represents material similar to the griphite of Headden and a comparison with the analyses by Headden bears out this conclusion as first pointed out by Dana (System of Mineralogy, p. 778).

Triplite is quite common in any of the Lithium bearing pegmatites.

147. GRIPHITE.

In 1891, W. P. Headden described this new phosphate of iron, manganese, etc., from the Riverton lode near Harney City (now the Everley Mica mine). It is best described in Headden's own words (24): "It occurs in the granite common in the district, in kidney-shaped masses, some of them weighing upwards of fifty pounds, but they are not numerous. Externally they are dark brown, due to oxidation which has taken place, in some cases, to the depth of a quarter of an inch, in others only on the surface. These masses enclose a few crystals of white mica, but are not penetrated by crystals of this mineral, which often adhere to the surface. Some of them show small seams of an almost white mineral with two cleavages nearly at right angles to one another; its composition has not been determined. It is easily recognized under the microscope, especially in polarized light, upon which it acts strongly, while the inclosing mineral has no effect upon it. In places there are dark patches visible only in pieces thin enough to transmit light. The mineral is amorphous and by reflected light has a dark brown color; by transmitted light in very thin pieces it is a yellowish brown, in thicker ones a brown color. It has a resinous-vitreous luster, an uneven to conchoidal fracture and no cleavage. In thin flakes it is translucent to transparent. Specific gravity, 3.401; hardness, 5.5 and is brittle. It is readily soluble in acids, fuses easily in the flame of a candle and reacts for manganese, iron and soda, before the blowpipe.

The material for analysis was carefully selected, only such pieces being taken as were thin enough to show by transmitted light that they were free from the dark patches and microscopic seams. The results were as follows:

	I.	II.	III.	IV.	V.	Mean
P_2O_5	38.61	38.22	38.45	38.49	38.86	38.52
MnO	29.74	29.74	28.97	30.08	....	29.64
CaO	7.70	7.66	7.66	7.08	7.28	7.47
Al_2O_3	9.94	10.34	10.09	....	10.14	10.13
FeO	3.83	4.14	4.01	4.00	....	4.00
MgO	0.14	....	0.16	....	....	0.15
Na_2O	5.52	....	5.70	5.68	....	5.52
K_2O	0.30	....	....	....	....	0.30
Li_2O	trace	....	trace	....	....	trace
H_2O	4.15	....	4.43	....	....	4.29
Cl	0.11	....	not det.	....	....	0.11
F	trace	....	....	....	....	trace
Insol.	0.14	....	0.18	....	....	0.16
	100.18		99.65			100.29

Griphite also occurs in claims on the south side of Battle Creek at Keystone in large rounded masses of a beautiful brown color and strongly resinous luster which are penetrated by small veinlets of albite. The color varies irregular from dark brown to chestnut brown to greenish brown. The fracture is conchoidal, the hardness 5.5 and the specific gravity 3.22. The streak is colorless. By transmitted light under the microscope the mineral is greenish yellow in color and is not amorphous as Headden believed, but proves to be biaxial (orthorhombic, monoclinic, or triclinic), although the exact crystallization cannot be determined.

So far the Riverton or Everly claim near Harney City and the one near Keystone are the only localities where this mineral is known to exist.

148. AMBLYGONITE Li (AlF) PO_4.

This mineral has already received mention in the discussion under cassiterite, where its association and occurrences have been briefly summarized.

Amblygonite occurs in pegmatites associated with other phosphates, more especially apatite and triplite, as coarse white cleavable aggregates and rounded masses frequently heavily coated with iron oxide on the outside. Cleavage takes place perfectly in one direction, while in two and sometimes in three other directions this mineral exhibits a more imperfect uneven cleavage. The name (signifying blunt angle) refers to the obtuse angles yielded by cleavage. The luster on the perfect cleavage plane is a poor pearly, while in other directions it is vitreous. The usual color is a milky white, but yellowish, greenish, and pale bluish tints are also occasionally shown. The mineral is translucent, has a colorless streak, equals steel in hardness, and has a specific gravity of 2.88 to 2.95.

Tests show that in much of the Black Hills amblygonite sodium replaces some of the lithium. A series of analyses made by Professor Coolbaugh at the State School of Mines yielded the following content in Li_2O in per cent : 9.87, 7.57, 6.021, 5.93, 4.87, 4.5, and 3.87 respectively. The theoretical percentage is 10.1%.

Amblygonite, together with spodumene, has been mined to some extent in the Black Hills and used for the extraction of lithia, which finds its chief use in medicine and in storage batteries. Only a few hundred tons are thus produced yearly by mines in the Harney Peak district. Amblygonite occurs in the Bob Ingersoll, Peerless and Christiansen (now the Hugo) claims near Keystone, and also in minor amounts in pegmatites near Glendale, Custer and Hayward.

149. OLIVENITE Cu_2 (OH) As O_4.

The occurrence of this arsenate of copper in the Etta mine was first mentioned by Schæffer (8). No specimens of this mineral are available for description.

150. KEHOITE 4 Al_2O_3 Zn O 5 P_2O_5 9 H_2O.

This phosphate of zinc and aluminum, which contains some iron and calcium replacing the aluminum and zinc respectively, was discovered and first described by Headden (34) as follows:

"About three years ago I received a number of minerals, mostly from the Merrit mine located at Galena, S. D., among which was the material described in this note. The mineral forms seams and bunches in the ore at one point in the mine. The ore is an argentiferous galena carrying zinc blende and iron pyrites. Goslarite occurs at other points in the mine, but was not found in the immediate vicinity of this occurrence. The nearest point at which the goslarite was observed was some 500 feet distant.

The material is white, amorphous and insoluble in water, but it yields a small amount of zincous oxide and phosphoric acid to concentrated hydric acetate upon continued boiling. Ammonic hydrate extracts rather more zinc than the hydric acetate, but does not dissolve it to any great extent. Concentrated potassic hydrate as well as the dilute hydric salts, i. e., HCl, HNO_3 and H_2SO_4 dissolve it readily and completely. The washed mineral forms an impalpable powder with a specific gravity of 2.34 at 15°; it is infusible, and in the closed tube yields an abundance of water. With soda on charcoal it gives an incrustation of zinc oxide, obtained with some difficulty—and reacts for alumina, when moistened with cobalt solution. Borax and phosphorous salt dissolve it readily; the beads are slightly yellow, while hot and colorless when cold. The saturated beads become opaque upon flaming.

The strongly ignited mineral is not completely soluble in HCl, HNO_3, or in aqua regia; the residue insoluble in these acids contains alumina and zinc, but no prosphoric acid or only traces of it. The air dried material loses when dried at 105-110°, 14.2% and loses but 3.34% additional between 115-120°. It required continued heating over a Kellogg burner to expel the last portion of water. The washed and air-dried material had the following composition:

	I.	II.	III.
Insoluble	1.76	1.78	1.74
H_2O	31.06	31.04	30.92
P_2O_5	26.76	26.74	26.78
SO_3	.50	.54	....
ZnO	11.64	11.54	11.58
CaO	2.70	2.90	....
Al_2O_3	24.84	25.62	....
Fe_2O_3	.78	....	....
MgO	.08	....	....
Cl	trace	trace	....
	100.02	100.16	

I propose Kehoite as the name of this mineral, after Mr. Henry Kehoe, to whom I am indebted for the material and who was the first to observe its occurrence."

151. DUFRENITE $Fe_2(OH)_3PO_4$.

This hydrous ferric phosphate has been identified by Hess (96) from the Tin Queen claim. There is no material on hand for description. See under Cacoxenite for description.

152. VIVIANITE $Fe_3P_2O_8 + 8 H_2O$.

This hydrated ferrous phosphate is also mentioned by Hess (96) from the Tin Queen. No specimens are available to the writer for study.

153. SCORODITE $Fe AsO_4 + 2 H_2O$.

This mineral occurs as a decomposition product of arseno pyrite (Fe As S) in several of the pegmatites and quartz veins of the Harney Peak district, as for example on the Etta and Peerless claims. It also occurs on the arsenopyrite bearing veins near Spokane and Glendale.

Scorodite occurs as an earthy greenish white incrustation, also in pale green poor fibrous crusts, filling seams and small cavities in arseno pyrite bearing pegmatites and quartz veins. The luster is dull, the streak is white. Hardness and specific gravity were not determined due to the powdery friable character of the material.

It fuses readily to a magnetic globule, yielding heavy white fumes and strong garlicky odor of arsenic. The name alludes to this odor.

Scorodite also occurs as a leek green coating or staining on weathered quartzites and quartz-schists in the vicinity of Keystone. The scales of scorodite have a dull to unctuous luster, a poor conchoidal fracture and a greenish white streak. The hardness is three and the specific gravity as determined by means of heavy solutions is 3.23.

It is easily fusible, yielding heavy white fumes of arsenic oxide and a magnetic residue. It is readily soluble in hydrochloric acid.

154. ARSENOSTRENGITE $Fe_2O_3(AsP)_2O_5\ 4H_2O$.

Near Glendale there occurs as the result of the decomposition of arsenical pyrites a delicate leek green to pale greenish yellow mineral in small botryoidal or reniform aggregates. The small kidney-like masses are quite impure, being mixed with some clay. The greatest part, however, is readily soluble in acids and yields decided tests for both phosphoric and arsenic acids, and for ferric oxide. Careful qualitative tests seem to show that phosphoric and arsenic acids are equally important. They also show a trace of alumina, and no lime magnesia, ferous iron, copper or other metal. In fact all tests seem to show that this mineral is an isomorphic mixture of scorodite ($FeAsO_4 2H_2O$) and strengite ($FePO_4 2H_2O$). These two minerals are placed in an isomorphous series, but as far as the writer is aware no intermediate compound has so far been noted. All analyses available to the writer show either a straight ferric arsenate or a straight ferric phosphate. For this intermediate mineral the author suggests the name arsenostrengite and refers the above mineral provisionally to this group.

The mineral has a hardness of 3, a specific gravity of 2.81. (This is much too light owing to clayey impurity.) The luster is earthy. It is easily fusible, yielding a black magnetic slag and arsenical odor. Heated in a closed tube, it yields much water. It is easily soluble in hydrochloric acid, but only with difficulty in nitric.

155. CACOXENITE $2FePO_4Fe(OH)_3\ 9H_2O$.

Some lithiophylite in the Etta mine shows delicate crusts of microscopic fibers or rarely an earthy coating of an iron phosphate. This is a canary yellow to yellowish brown color and is associated with another phosphate, probably dufrenite, which is usually green in color. Careful tests with heavy solutions also tend to show that the canary yellow phosphate is a trifle lighter, although the difference cannot exceed 1 in the second decimal place, the specific gravity of both running about 2.32 +, respectively. Both give tests for ferric phosphate, hence are referred to dufrenite and cacoxenite respectively. Both are about 3.5 in hardness. They are both soluble in acids, and fuse to a black magnetic slag, coloring the blowpipe flame a faint bluish green. The yellow phosphates are not as easily fusible as the green. Both yield water when heated in a closed tube. On weathering both turn dark brown, due to the formation of limonite.

URANITE GROUP.

Here we include a series of uranium-bearing phosphates, of which the following occur in the Black Hills:

Torbernite $Cu\ (UO_2)_2P_2O_8 + 8\ H_2O$.
Autunite $Ca\ (UO_2)_2P_2O_8 + 8\ H_2O$.
Uranocircite $Ba\ (UO_2)_2P_2O_8 + 8\ H_2O$.

These minerals frequently go under the name of uranite and are known respectively as copper, lime or barium-uranite.

156. TORBERNITE $Cu\ (UO_2)_2P_2O_8 + 8\ H_2O$.

This mineral occurs in minute square tabular crystals of bright grass green color in vugs and small cavities in the blue siliceous gold ore of Lower Cambrian age, at the Ross Hannibal mine about one and one-half miles southeast of Terry.

None of the crystals attain a size larger than one-fourth of an inch square, while the majority are about one-eighth inch square. The top of these crystals has a fine pearly luster, while the sides are weakly metallic. The streak is pale green, the specific gravity about 3.5, and the hardness 2.5—the mineral just barely yielding a scratch by the finger nail. Torbernite possesses excellent basal cleavage, which yields an extremely thin almost micaceous, but brittle flake.

Some torbernite also occurs in very small micaceous aggregates, formed by the overlapping and intergrowth of a number of the small square crystals. More commonly we find the torbernite arranged in beautiful radiating fibers pressed out flat in minute fissures in the blue siliceous ore, which yield fine almost circular rosettes up to three-fourths of an inch in diameter.

So far torbernite has not been reported from elsewhere in the Hills, although it is probably present at the Poisoned Ox claim, a copper prospect near Pactola, from which a green uranium mica has been reported.

Torbernite is also common as a thin coating on masses of black tourmaline and in their fracture planes, in certain pegmatites. This is usually bright to dull green in color, and is rarely more than a delicate staining. It occurs in many pegmatites near Keystone, accompanied by autunite. The latter mineral is, however, entirely confined to muscovite and beryl, while the tobernite is restricted to black tourmaline. These minerals evidently exerted a selective action on the uranium-bearing solutions or vapors, the muscovite precipitating a lime uranium phosphate, while the tourmaline precipitated a copper uranium phosphate.

157. AUTUNITE $Ca(UO_2)_2P_2O_8 + 8H_2O$.

The lime uranite occurs as a rare mineral in pegmatites near Harney Peak and in the porphyries (phonolite) on Annie creek west of Portland. In the latter locality crystals are very rare, and the autunite usually occurs as a very thin micaceous coating or a series of thin irregularly shaped flakes or as a number of small partially radiating moss-like aggregates, coating minute fissures in the porphyries. The cleavage is excellent, yielding thin brittle laminæ of a lemon-yellow color which are weakly transparent. The luster varies from dull silky to adamantine, while an occasional square crystal shows pearly luster. The streak is deep yellow, the hardness about equal to the finger nail, and the specific gravity 3.07. It is associated with limonite, and a little fluorite.

Autunite occurs to quite an extent in various pegmatite dikes in the Southern Hills, as a thin bright yellow coating on flakes and crystals of muscovite and as seamlets in their cleavage planes. Such was collected on the Bob Ingersoll, Peerless, Everly, Etta and other claims near Keystone. It is nearly always associated with torbernite (which see).

158. URANOCIRCITE Ba $(UO_2)_2P_2O_8 + 8\ H_2O$.

This mineral has been reported as occurring in several localities in the northern Hills as an accessory mineral in the siliceous gold ores, by Irving (74). No specimens are available for description.

159. URANINITE (Pitchblende).

In 1885 L. W. Stillwell (10) reported the occurrence of uraninite on Bald Mountain. No specimens are available for description.

160. BINDHEIMITE.

See E [illegible] Econ. Geol. [illegible] 1920.

A hydrous antimonate of lead believe to be bindheimite occurs as an alteration product in the jamesonite ores of the Black Hills, usually as earthy and incrusting masses or as a powdery material filling small fissures and cavities. The material is friable, has a dirty canary yellow color, but varies from pale yellow to yellowish brown, and is rarely white. The streak is like the color, only paler in the colored varieties. The pure powder if rubbed over calcite will leave a scratch, but appears to leave no mark on fluorite, thus indicating its hardness to be about 3.5. The specific gravity is 4.8.

It is easily fusible, yielding when mixed with borax or soda a brittle antimonial lead button. The mineral appears to be insoluble in dilute nitric acid and only partially soluble in dilute hydrochloric acid.

161. DIADOCHITE $(2\ Fe_2\ O_3.\ P_2\ O_5.\ 2\ SO_3.\ 12\ H_2O)$.

This rare mineral has only been found in one locality, on a gold claim belonging to Mr. Wm. Gerard, near Keystone, and here only in small amounts.

It occurs as minute stringers and thin stalactitic coatings in a protected cavity on the wall of a small open cut. The country rock is a siliceous muscovite schist, at this locality cut by a few quartz-pyrite veinlets. The oxidation of the pyrite causes the formation of sulphuric acid, which, interacting with the apatite [$3Ca_3 P_2 O_8 + Ca (Cl.F)_2$] occurring in small amounts in the schist, sets free the necessary phosphoric acid needed in the formation of diadochite. It is also possible that the phosphoric acid comes from decomposing organic material.

The diadochite is a deep yellowish brown or dark amber color, has a rich resinous luster, and is clear and transparent. It is very brittle, slightly softer than calcite (3), and very light (Sp. Gr. determined by heavy solutions (2.051).) The streak is colorless, the fracture conchoidal. It fuses easily with much swelling into a magnetic residue, rarely into a magnetic globule. If heated in a glass tube, it yields much water and at high heat, sulphuric acid. It is soluble in hydrochloric and nitric acids, more readily in the former.

GROUP OF OXYGEN SALTS.

e. Sulphates and tungstates.

Under this group we include those minerals that are salts of sulphuric acid (H_2SO_4) and of tungstic acid (H_2WO_4).

THE BARITE GROUP.

This is an isomorphous group of orthorhombic minerals of which the following are known from the Black Hills:

Barite $BaSO_4$.
Celestite $SrSO_4$.
Anglesite $PbSO_4$.
Anhydrite $CaSO_4$.

162. BARITE $BaSO_4$.

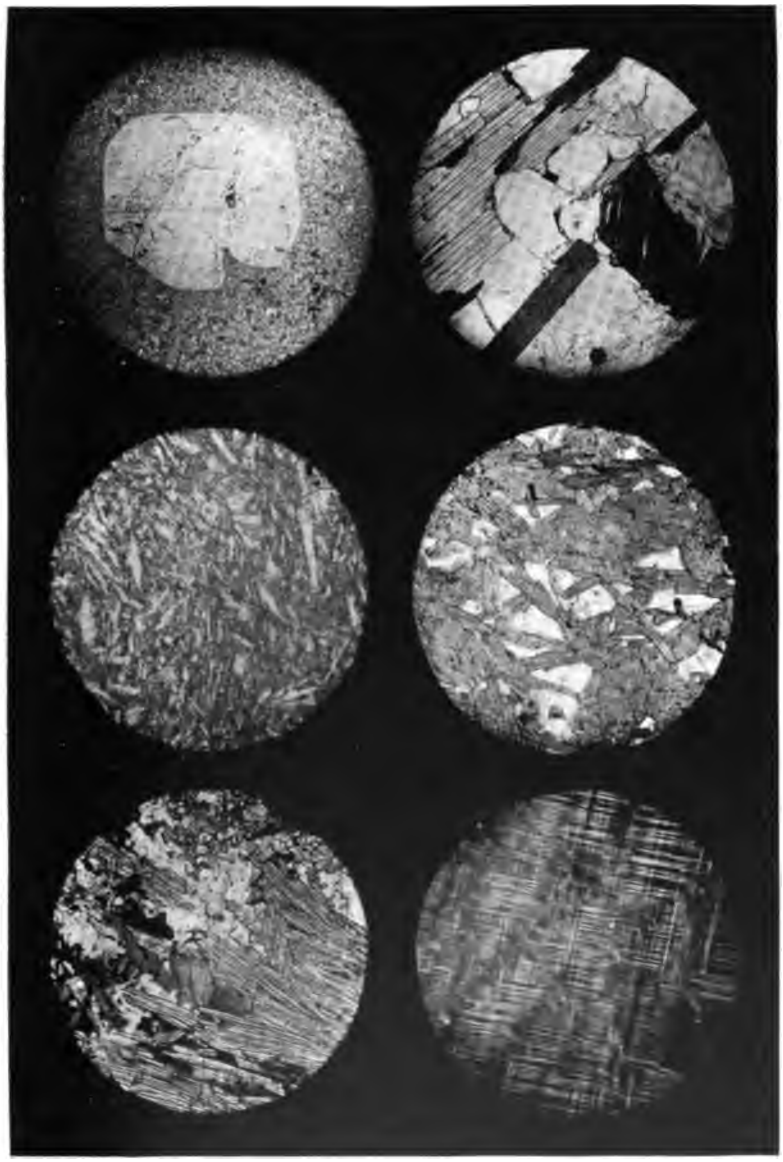


PLATE XXV: Photomicrograph of Thin Sections of Black Hills Rocks.
Rhyolite Porphyry, Lead. Granite, Custer.
Tinguaite, Englewood. Amphibolite, Keystone.
Homestake Ore, Lead. Microcline Crystals, Custer.

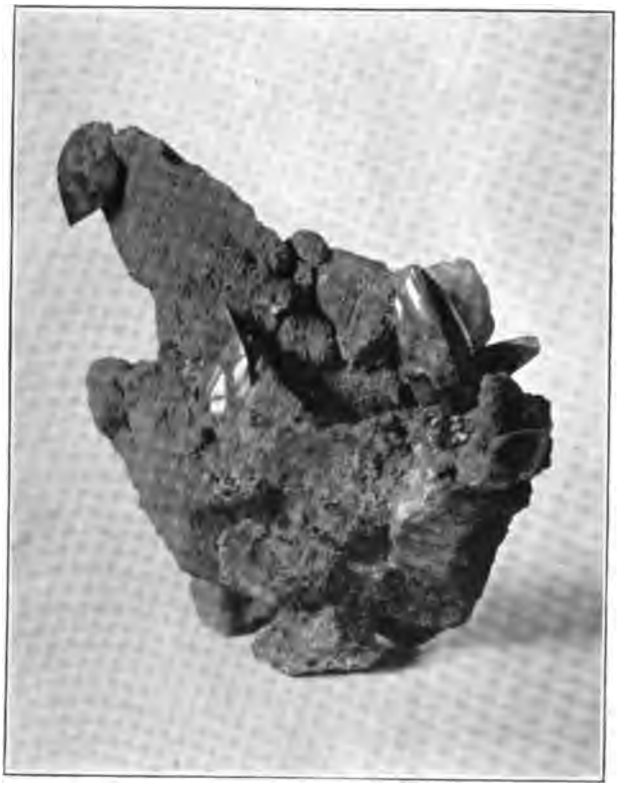


PLATE XXVI:
Barite on Golden Calcite,
Cheyenne River.

This mineral, also known under the names of barytes and "heavy spar," is of quite common occurrence in several localities in the Black Hills area. The best crystals occur in cavities in concretions in the Pierre shales, especially along the Cheyenne river, where they are associated with "golden calcite," which has already been described.

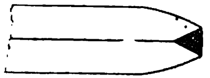


Fig. 71.

The crystals are yellow, amber, smoky brown, or wine colored, and are quite transparent. They are prismatic in shape and elongated parallel to the b axis. The unit prism (a:b:αc) and the domes (a:αb:c) are present. The former are often rough, due to the presence of fine striations, while the latter are usually curved right and left and also backward and forwards, and in the larger crystals are occasionally marked by striations due to oscillatory growth and by small triangular etch figures. The possible presence of a second dome cutting the b and c axis is indicated by a slightly curved flattening marked by fine striations near the intersections of the other domes and the prism. Crystals up to 1.5 inches in length are quite smooth and regular; those of larger size have rougher surfaces. A crystal about one foot in length and about the diameter of a man's wrist has been reported which appears to be the largest crystal so far known from this locality. The specimens in the State School of Mines collection average less than two inches in length and about one inch in greatest diameter.

The cleavage is poor and hardly noticeable in most of these crystals. The hardness is about the same as that of clear calcite crystals (3) and the specific gravity is 4.405.

Barite also occurs as radiating prismatic aggregates in joint planes of the Pierre shales.

About eight miles northwest of Custer, evidently in Pahasapa (?) limestone, barite occurs as milky white, weakly translucent masses, which are quite fine grained and have a dull to pearly luster. These masses are readily scratched by a knife and their specific gravity (4.443) is immediately noticeable. Barite containing some strontium also occurs as irregular nodules and as concretions made up of finely columnar aggregates in the Sundance formation ,as for example near Sturgis and Tilford.

Small nodules and aggregates made up of an intergrowth of white tabular crystals are found in the Graneros formation near Rapid City. The small crystal plates show the unit prism and the basal pinacoid. These nodules show a crystalline surface and have the small plates of barite arranged in a series of concentric irregular circles giving a rosette-like appearance.

At Lead, tabular crystals of barite occur as a gangue in the wolframite ores. The crystals are usually milky white, but occasionally gray, pink or stained brown, have a pearly to vitreous luster, and show excellent cleavage parallel to the prism faces and the basal pinacoid, which are the only forms present in these crystals. Occasionally the plates are arranged in radiating aggregates, but more often they occur in abundance as well defined crystals irregularly oriented and scattered through the siliceous wolframite ore and the barren adjacent rock. Barite also occurs in the Etta mine and in quartz veins in the Southern Hills and may be expected as a gangue in most of the mines of the Black Hills.

163. CELESTITE $SrSO_4$.

The only locality which has furnished celestite in the Black Hills is a fluorite-bearing vein on the Hidden Treasure ground about two miles northwest of Lead.

Specimens in the collection of the State School of Mines show an aggregate of cleavable masses of fluorite, colorless, milky, or faint purple in tint, cutting through white quartzite and coated on one side by radiating and reticulated plates of white celestite. The plates show no crystal outlines, but exhibit excellent flat cleavage planes and on these a decidedly pearly luster. The streak is colorless, the hardness 3.5, and the specific gravity 3.94.

It fuses readily, coloring the flame crimson, and leaving a white globule. The flame coloration serves as the readiest means of distinguishing this mineral from barite.

164. ANGLESITE $PbSO_4$.

The lead sulphate, anglesite, is the common alteration product of galenite, which in turn readily alters to the lead carbonate, cerussite. Anglesite is usually a constituent of some importance in the lead carbonate ores of the Black Hills, especially those still containing unaltered galenite. Thus it occurs in the lead ores at Galena, Carbonate, Spokane, Black Buttes, etc.

In appearance it closely resembles cerussite, being colorless when pure, but is usually yellow, brown or red, due to admixtures of clays and iron oxides. The luster is resinous to adamantine, the hardness 3, and the specific gravity of pure material is about 6.3.

It is readily confused with cerussite, but may easily be distinguished by the fact that it does not effervesce when treated with acids.

Angelsite is very easily fusible and if mixed with soda can readily be reduced to native lead. It is a lead ore of some importance.

165. ANHYDRITE $Ca\ SO_4$.

Mr. Samuel Scott reports anhydrite from veins on Spring creek, ten miles northwest of Custer (44). No material is available to the writer. Although there is no definite information, it is probable that anhydrite occurs with some of the gypsum deposits of the Black Hills.

166. GOSLARITE $ZnSO_4 + 7\ H_2O$.

This mineral is reported by Headden (34) as occurring in the Merritt mine, near Galena. Nothing further is stated regarding this mineral, and no specimens are available for description.

167. GYPSUM $CaSO_4 + 2\ H_2O$.

Gypsum is especially common on the outer border of the Black Hills proper, where it occurs in the following forms:

1st. As selenite, the crystalline variety
    a. in well defined individual crystals or
    b. as clear transparent plates and seams.

2nd. As satin spar—a fine, fibrous variety of decided silky luster.

3rd. Massive—as rock gypsum—a dense fine grained variety occurring in well defined strata, up to thirty feet in thickness.

Selenite in well defined crystals occurs in some abundance in the Pierre shale near Hermosa and in the Fuson shale south of Belle Fourche. The Carlisle formation also occasionally affords good crystals.

The common forms are well shown on the accompanying plates.

The crystals are monoclinic, showing the prism (a:b:αc) and the clino pincoids (αa:b:αc) in combination with the domes (αa:b:c). The prism faces and the clino pinacoids are often striated. Twin crystals are very common either of the penetration or contact type. The latter have the appearance of an arrowhead and are hence known as arrowhead or swallowtail twins. They are usually colorless and transparent, but an occasional specimen is milky white, and due to the presence of cleavage planes transparent varieties are often quite impervious to light. Cleavage is especially perfect parallel to the clino pinacoid, while it is less perfect and often absent in two other directions, parallel to (a:αb:αc) and parallel to (a:αb:c). The crystals have a hardness of 2 and are easily scratched by the finger nail. Their specific gravity is 2.23. The luster varies from pearly on the perfect cleavage faces to vitreous in other directions in transparent varieties, while on milky white specimens the luster is dull. The streak is colorless. All gradations are shown from perfect crystals to transparent foliated masses, seams and plates, which possess no crystal planes with the exception of cleavages. Their surfaces are often warped and curved and full of depressions and re-entrant angles due to irregularities in growth. The selenite plates are often arranged in well defined stellate groups and more rarely into imperfect concentric circles yielding rosettes.

Seams of gypsum frequently exhibit a beautiful fibrous structure when on account of the silky luster shown by the fibers they are known as satin spar.

Rock gypsum is the name applied to massive dense varieties occurring in well defined layers or strata. The Spearfish Red Beds contain the important gypsum beds of the Black Hills region. The snow white gypsum usually furnishes prominent exposures in the bright red shales and due to superior resistance to weathering, yields striking white capped buttes. The Spearfish red beds give rise to a wide red valley which encircles the whole of the Black Hills. According to Darton the gypsum occurs in several distinct beds sometimes four or five, varying up to 33 feet in thickness, of which the more prominent often cover great areas. At Hot Springs the principal beds of gypsum have a thickness of 33½ feet, at Hermosa 15 feet, at Cascade Springs 20 feet, at Fanny Peak 30 feet, northeast of Cambria 25 feet, at Cambria the best gypsum bed is 12 feet in thickness.

The gypsum varies from pure white to gray in color and is frequently mottled brown or red by iron oxides. It is used in the manufacture of stucco or wall plaster, plaster of Paris, Keene's cement, etc. Pure white varieties are known as alabaster and furnish material suitable for interior decoration. It is used to some extent by Indians for the carving of souvenirs such as tomahawks, etc., which are sold to tourists.

Stucco plants are located at Black Hawk, Sturgis, Hot Springs, Spearfish and Rapid City.

The following analyses show the purity of these gypsum beds:

	HOT SPRINGS.			BLACK HAWK.		
	I.	II.		I.		II.
SiO_2	.12	.09		.16		1.00
$Fe_2O_3Al_2O_3$	.13	.06		.12		.46
SO_3	45.77	44.86		32.27	$MgCo_3$	trace
CaO	33.00	32.89		44.59	$CaSO_4$	70.91
MgO	.10	.28	$MgCo_3$	.58	$CaCo_3$	8.13
Loss on ignition	20.85	21.41		20.48		20.14
	99.97	99.59		98.20		100.64

Analyses of the Hot Springs material are by Prof. M. F. Coolbaugh of the State School of Mines, the others are by Chester G. Ehle (Graduating Thesis 1911).

In minor amounts and of little importance gypsum also occurs as a gangue mineral in several of the ore deposits of the Black Hills, as for example in the refractory siliceous ores of the Northern Hills. As seams and veinlets it is also associated with coal as at Cambria, Wyoming, and as minute incrustations it occurs associated with golden calcite and barite in some of the concretions in the Pierre shale along the Cheyenne river.

168. MELANTERITE $FeSO_4 . 7 H_2O$.

This mineral also known as copperas and as green vitriol is quite common as an efflorescence on pyrite that is exposed to weathering. Thus the pyritous slates of the central Black Hills show this mineral usually as a white pulverulent powder or as white botryoidal crusts or as earthy veinlets and seams. This mineral is very easily soluble in water, hence is removed by circulating solutions. These quite frequently form mineral springs, such for example as those along Iron Creek, west of Hayward. When redeposited in railroad or mine tunnels and workings the melanterite is frequently in beautiful fibrous aggregates or in fine botryoidal or stalactitic structures. These are usually sea green in color when in place, and are frequently mistaken for copper staining and more especially for copper sulphate—chalcanthite. This latter mineral is bright azure blue in color and may also be distinguished by moistening and placing for a few minutes on a knife blade when the latter will become covered with a thin coating of copper. When the melanterite is exposed to the air it tends to dry out and oxidize, first turning white and becoming pulverulent, and later turning a yellow to yellowish brown color.

Melanterite occurs in some abundance in pyrite deposits near Deadwood in stalactitic structures. In mine tunnels near Hayward it is quite abundant as a silky fibrous efflorescent coating on the walls. It is a delicate green in color, which when exposed to the light rapidly fades, leaving the mineral pure white. The mineral is somewhat tough and the fibers are slightly flexible. They are easily scratched by the finger nail and very light. (Sp. Gr. 1.85). It is derived by leaching from the country rock, here a pyritous slate.

In small amounts it is quite common anywhere on pyrite or marcasite. Thus iron sulphide nodules and concretions common near the outer borders of the Black Hills and especially in the Pierre Shales, are usually coated with this mineral in the form of a white powder.

Melanterite gives a sweetish nauseating and astringent taste which serves as a ready means of identification.

169. CHALCANTHITE $CuSO_4$ 5 H_2O.

This mineral is more commonly known as blue vitriol. It is frequently formed by the oxidation of copper sulphides (such as chalcocite and bornite). It is quite easily soluble in water and occurs in the ground water of various copper prospects, although often in only minute amounts. When these solutions come in contact with mine timbers or with iron, such as steel rails, native copper is precipitated. As an efflorescent coating, chalcanthite is very rare, a little having been observed in various localities as at Sheridan, near Harney, and near Deadwood. It occurs in minute stalactite forms of deep blue color. The streak is white. It has a nauseating, metallic taste. The hardness is slightly harder than the finger nail. The specific gravity is about 2.1. The taste and deep blue color will serve to identify this mineral readily.

170. KALINITE KAl $(SO_4)_2$ $12H_2O$.

Kalinite or potash alum occurs in small amounts in a a tunnel on the Burlington railroad near Mystic and in railway tunnels near Lead. as a white pulverulent efflorescence. This is about 2 in hardness, is very easily soluble in water and has a decided astringent taste.

This mineral is restricted to slates where it is formed by the action of sulphuric acid, liberated in the oxidation of pyrite, on aluminum compounds.

171. HALOTRICHITE Fe Al_2 $(SO_4)_4$ 24 H_2O.

This mineral occurs sparingly, associated with melanterite and Kalinite and owes its origin, as does the latter mineral, to the action of sulphuric acid on slates.

Halotrichite occurs in pulverulent crusts and veinlets, is pale yellowish in color, very soluble in water, and has the taste of ink. It fuses very easily, giving the odor of burnt matches, when highly heated, and becoming weakly magnetic. It is so much like Kalinite in appearance and taste that a chemical test is necessary for distinction. Small amounts of this mineral have been collected from the tunnel of the Burlington Railroad near Mystic.

172. PICKERINGITE $Mg SO_4 Al_2 (S O_4)_3 + 22 H_2O$.

A pyritiferous amphibolite occurring in the Holy Terror Mine, at Keystone, when exposed to weathering is frequently coated with a white efflorescence of this mineral. This is formed by the action of the free sulphuric acid, which is liberated during the oxidation of the pyrite and pyrrhotite on the minerals of the amphibolite. The efflorescence of pickeringite is especially noticeable on the dumps of the Holy Terror and Keystone Mills, where it always accompanies the amphibolite rocks and where it is quite abundant in isolated protected spaces between and under rocks.

The mineral has a dull, earthy luster, and a white to pale grayish white color and streak. It is very friable, and much of it is pulverulent. It is readily soluble in water and has a bitter, nauseating taste, very much like that of epsom salts. It carries small quantities of lime, which replaces part of the magnesia in the formula given above. If it be placed in a closed tube and heated, it yields large quantities of water and finally dense white fumes of sulphur trioxide and some sulphuric acid which condenses in the tube.

The Holy Terror is the only locality in the Black Hills where this mineral has been found so far.

173. AMARANTITE $Fe_2O_3 2SO_3 7 H_2O$.

This occurs associated with melanterite near Hayward and is described as follows by C. C. O'Harra: (Bulletin No. 1, School of Mines.)

"A minutely crystallized brownish or wine-colored mineral occurs in very small quantity with the melanterite. This mineral is also an iron sulphate. The general characters of the mineral indicate that it is amarantite, although positive evidence of this has not yet been definitely established."

174. JAROSITE K_2O $3Fe_2O_34SO_3$ 6 H_2O.

This mineral was well described by Headden (25) in the following words:

"This mineral is found as a coating in and sometimes partly filling larger cavities in the auriferous quartzite which is the chief ore obtained in the Buxton mine, Lawrence county, South Dakota. It also occurs in the smaller cavities of the rock and in distinct crystals associated with small quartz crystals, which cover old fracture-planes in the rock. The jarosite, where it is free from limonite, has a golden yellow color and the mass is composed of scales which under the microscope appear as six-sided plates. The largest crystals observed were about 2mm. in breadth and have a light brown color; their form could be recognized with the aid of a good magnifier as a combination of a rhombohedron and the basal plane.

The purest material that I could select gave:

Quartz	6.10	Quartz deducted
SO_3	28.46	30.29
AS_2O_5	2.36	2.51
Fe_2O_3	46.27	49.28
CaO	.39	.42
Na_2O	4.35	4.62
K_2O	1.47	1.57
H_2O	10.55	11.24
	99.95	99.93

175. COPIAPITE 2 Fe_2O_3. 5 SO_3. 18 H_2O.

This ferric sulphate occurs as a yellow incrustation of granular character associated with some melanterite in the Lady of the Hill Mine northwest of Silver City. It is a sulphur to lemon yellow color, very friable and possesses a white streak. It is very easily soluble in water, and has an astringent nauseating taste. It gives decided tests for ferric iron, water, and the sulphate radicle and a poor test for alumina. Microscopic examination indicates it to be long to the biaxial minerals (orthorhombis, monoclinic or triclinic). These tests seem to indicate copiapite to which the mineral is hence referred.

THE WOLFRAMITE GROUP.

This group includes tungstates of iron and manganese and intermediate compounds which crystallize in the monoclinic system.

The following are included:

176. FERBERITE Fe WO_4.

177. WOLFRAMITE (Fe Mn) WO_4.

178. HUEBNERITE Mn WO_4.

All three of these minerals are represented in the Black Hills, but wolframite is by far the more common of the three. On account of the fact that we have complete gradations from the manganese tungstate on the one hand, to the iron tungstate on the other, these minerals are very much alike and frequently necessitate an exact specific gravity determination or a chemical test for distinction.

Pure manganese tungstates are very rare and the Black Hills varieties carry small percentages of iron. Pure iron tungstate is unknown in nature, but always carries some manganese.

Wolframite occurrences in the Black Hills may be classified as follows:

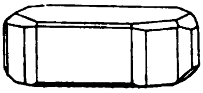
1. In pegmatites and pegmatitic granites associated with columbite and cassiterite.
2. In quartz veins.
3. As replacement deposits in dolomitic sandstone, and
4. In placers.

The presence of wolframite in the pegmatites and quartz veins of the Southern Black Hills and of the Tinton district was known soon after the discovery of tin. Due to the small amounts of tungstate present, these deposits have received little attention and aside from several car loads mined by the Reinbold Metallurgical company, no tungsten ore has been produced on a commercial scale. Lately (1913) deposits about three miles east of Hill City have been opened up and a small concentrating plant has been erected to handle the ores.

In the pegmatites the wolframite occurs as small irregular grains with dull luster, except on the cleavage planes where it is brilliant adamantine. The color is black and the streak reddish brown. The amounts of wolframite so present is small wherever the pegmatites are rich in feldspàrs, micas or lithium minerals. In the more quartzose developments of the pegmatites and in the quartz veins wolframite is more abundant.

Only when the wolframite grains project into a cavity do they possess crystalline outlines. Usually they occur as flat plates up to six inches in extreme diameter and a half inch in thickness, or in irregular masses, aggregates of tabular individuals or indistinct grains.

C. H. Warren (63) describes the following forms of minute crystals of ferberite:



Ferberite (after Warren)

Pinacoids—	a :αb :αc	(100)
	αa :b :αc	(010)
	αa :αb :c	(001)
Prisms—..	a :b :αc	(110)
	a :2b :αc	(210)
	11a :7b :αc	(7.11.0)
Domes—	2a :αb :c	(102)
	αa :b :c	(011)
Pyramid—	2a :2b :c	(112)

On huebnerite from the Comstock mine, in Lawrence county, Headden (85) identified the following forms:

Pinacoid—	a :αb :αc	(100)
Prism—	a :b :αc	(110)
Domes—	a :αb :c	(101)
	αa :b :c	(011)
	2a :b :αc	(120)

and probably two pyramid faces (?)

It may be possible that the above crystal of ferberite described by Warren is from the vicinity of Lead, although at the time it was described the presence of this mineral at Lead was yet unknown.

The color of the mineral varies; iron rich varieties are invariably black and have a dark gray or brownish gray streak. As the manganese increases the color tends to become brown and the crystals columnar instead of tabular. Huebnerite is usually black, but much of the material from the Comstock Mine consists of hair brown to dark brown columnar, bladed aggregates, that have a resinous to admantine luster and a reddish brown streak. Similar huebnerite occurs in quartz veins on Sunday Gulch, just east of St. Elmo Peak. The hardness is about equal to ordinary glass (5.5), the manganese high varieties tending to be harder. Ferberite and wolframite are opaque, but thin cleavage pieces of the huebnerite transmit reddish brown light faintly. The specific gravity of the Manganese high varieties is lower than that of the others, being 7.28 and 7.41 respectively for the fragments tested. All of these minerals are readily fusible, but huebnerite less so than wolframite or ferberite. The latter two yield magnetic globules.

The first two analyses are by Headden (86), the other by M. F. Coolbaugh:

	Huebnerite Comstock Mine.	Wolframite Sunday Gulch.	Hill City.
WO_3	75.12	74.46	70.84
MnO	20.54	3.29	6.71
FeO	3.01	19.90	17.61
CaO	1.04	1.05	Tr. SnO_3
Insoluble	...	.42	
Ignition loss	...	.75	
	99.71	99.87	

The wolframite decomposes somewhat readily to iron oxides and to scheelite, the calcium tungstate.

The more important localities for wolframite are the Black Metal, the Wolfram, the Good Luck, the Vida May and other claims near Hill City, the finest specimens coming from the Addie Mine, where it is associated with much graphite. These minerals are also known in quartz veins near Oreville and elsewhere about Harney Peak and the Nigger Hill district.

Ferberite occurs as irregular black finely granular masses in pegmatite about three-quarters of a mile northeast of Hill City.

The third wolframite occurrence, that is replacements of dolomitic sandstones which occurs in the vicinity of Lead has been in the past the most important and for several years furnished small amounts of valuable ore.

These deposits have received incidental mention in the discussion of sylvanite and also barite. Irving considers these wolframite deposits simply a basic phase of the ore-bearing solutions which brought in the gold and other constituents and formed the refractory siliceous ores of the Northern Black Hills.

Wolframite has been found in these ores west of the Homestake mine and also about two miles southeast on the Wasp No. 2 mine.

The true nature of this black mineral was not learned until 1899, when O. A. Reitz, a teacher in Lead High School, determined it to be wolframite.

The wolframite occurs as fine granular masses in streaks up to two feet in thickness in the siliceous ore. Scheelite both yellow and green being associated with it in druses and also as disseminated granular masses of limited abundance. Only when protruding into cavities does the wolframite show crystal faces, but the individual crystals are so small that no determination of crystal forms can be made without measurements with a reflection goniometers which was not available to the writer. Associated with the wolframite in druses occur in addition to scheelite, minute crystals of fluorite, quartz, pyrite, calcite, occasionally jarosite, and quite frequently barite. This latter mineral is also often quite abundant in the massive ore occurring as irregularly disseminated tabular crystals.

The wolframite is usually black to brownish black in color, has a submetallic to adamantine luster, and a reddish brown streak. Its hardness is 5.5 and the specific gravity of select specimens is 7.05. These were probably impure.

The following analyses are by W. F. Hillebrand and are quoted by J. D. Irving (74):

	Two Strike Mine, Yellow Creek.	Harrison Mine, Lead.
SiO_2	12.87	9.60
WO_3	61.50	61.70
Fe_2O_3	3.85	12.65
FeO	9.18	....
Al_2O_3	.52	....
MnO	8.21	7.21
CaO	.93	5.39
SrO	.02	....
BaO	.04	....
K_2O—Na_2O—Li_2O	.08	....
H_2O below 105 C.	.20	....
H_2O above 105 C.	.87	....
As_2O_5	1.25	....
P_2O_5	.12	....
V_2O_5	trace	....
S or SO_3	trace	....
	99.64	

A limited amount of such ore has been produced from the Durango, Harrison, Sula, Hidden Fortune, Plate 20, Reddy and Golden Crown mines near Lead, and the Two Strike and Wasp No. 2 mines on Yellow Creek. The total production does probably not exceed a hundred tons.

A limited amount of wolframite occurs in placer form. It is usually rare, except near the source of supply, as it is somewhat readily altered to iron oxides and scheelites. Wolframite is reported in placers from both in the Southern Black Hills and in the Nigger Hill district.

179. SCHEELITE $CaWO_4$.

The conditions of occurrence for this mineral in the Black Hills may be summarized as follows:

1. In pegmatites.
2. In quartz veins.
3. As replacements of sandy dolomites.
4. As a decomposition product of wolframite and ferberite.
5. In placers.

It has practically the same occurrences as wolframite with which it is always associated, except that it occurs as a secondary mineral in addition, resulting from the breaking down of the tungstates of the wolframite group.

As an original constituent in pegmatites and quartz veins, scheelite occurs rarely with wolframite in the Harney Peak and the Nigger Hill district. The scheelite is in small disseminated grains and occasionally in small masses as at Bear Gulch. These are yellow, white or green in color, have a vitreous to waxy luster, good cleavage, a hardness of 5, and a specific gravity of 6.05. They are with difficulty fusible and if treated with hot hydrochloric acid go into solution, leaving a canary yellow precipitate of tungstic oxide.

Associated with huebnerite, scheelite occurs both as primary and secondary mineral in quartz veins on Sunday Gulch, east of St. Elmo Peak. The Reinbold Metallurgical company has opened up this deposit by inclined shaft and drift and has produced and shipped to Germany several carloads of this ore.

In the wolframite deposits near Lead, scheelite occurs as scattered grains in the ore and as minute crystals in vugs and cavities. These are usually yellow in color, but occasionally green, have a resinous to adamantine luster and show good cleavage. They are less than glass in hardness, and have a colorless streak. The crystals are so small that no forms could be determined, but square tabular habits are the more common.

The secondary scheelite occurs in minute veins and seams and as crystalline druses on weathered wolframite ores wherever these occur. Such scheelite may be white, yellow, brown, or green in color and does not differ essentially in characteristics from that already described. It and the iron oxides are the common decomposition products of Black Hills tungsten minerals.

To some extent scheelite occurs in placers. Since it is a soft and cleavable mineral it is never transported far away from the source. Specimens of scheelite several pounds in weight have been found in the placers of Bear Gulch and Sunday Gulch.

180. CUPRO SCHEELITE (CaCU) WO_4.

Dr. Herman Reinbold reports the finding of a number of crystals of this mineral at the Edgewater Claim near Spokane (private communication). No specimens are available for description.

181. WULFENITE $Pb Mo O_4$.

This lead molybdate occurs as minute square tabular crystals of brilliant adamantine luster, and pale yellow color in the upper portion of lead deposits, as for example at Spokane, at Galena, and at Carbonate.

Most of the crystals are less than ¼ inch in diameter and are exceedingly thin. The forms present as determined by inspection are:

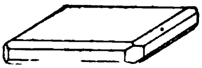


Fig. 73.
Wulfenite.

Prisms—	
1. a :a :∞c	(110)
2. a :∞a :∞c	(100)
Pinacoid—	
3. ∞a :∞a :c	(001)
Pyramid—	
4. 2a :∞a :c	(102)

The crystals possess good cleavage parallel to a pyramid face. They have a hardness of 3, a specific gravity of 6.81, and a colorless streak. They are very easily fusible and are readily reduced to native lead.

Vanadinite, which is associated with the wulfenite, may readily be distinguished by its six-sided crystals.

Wulfenite does not occur in sufficient abundance to be of any economic importance in the Black Hills.

VIII. THE HYDROCARBONS.

There are a large number of different hydrocarbon, compounds and mixtures occurring in nature either in the solid, liquid or gaseous state which are not by best authority included in the realm of minerals. Natural gas, oil, asphaltum, mineral resin and coal are such substances represented in the Black Hills. These differ from true minerals in the fact that they are of organic origin, posses no definite chemical composition, and have no definite crystalline form. On account of their economic importance, however, and the consequent public interest, they are discussed very briefly in this bulletin. No full adequate discussion is presented here,

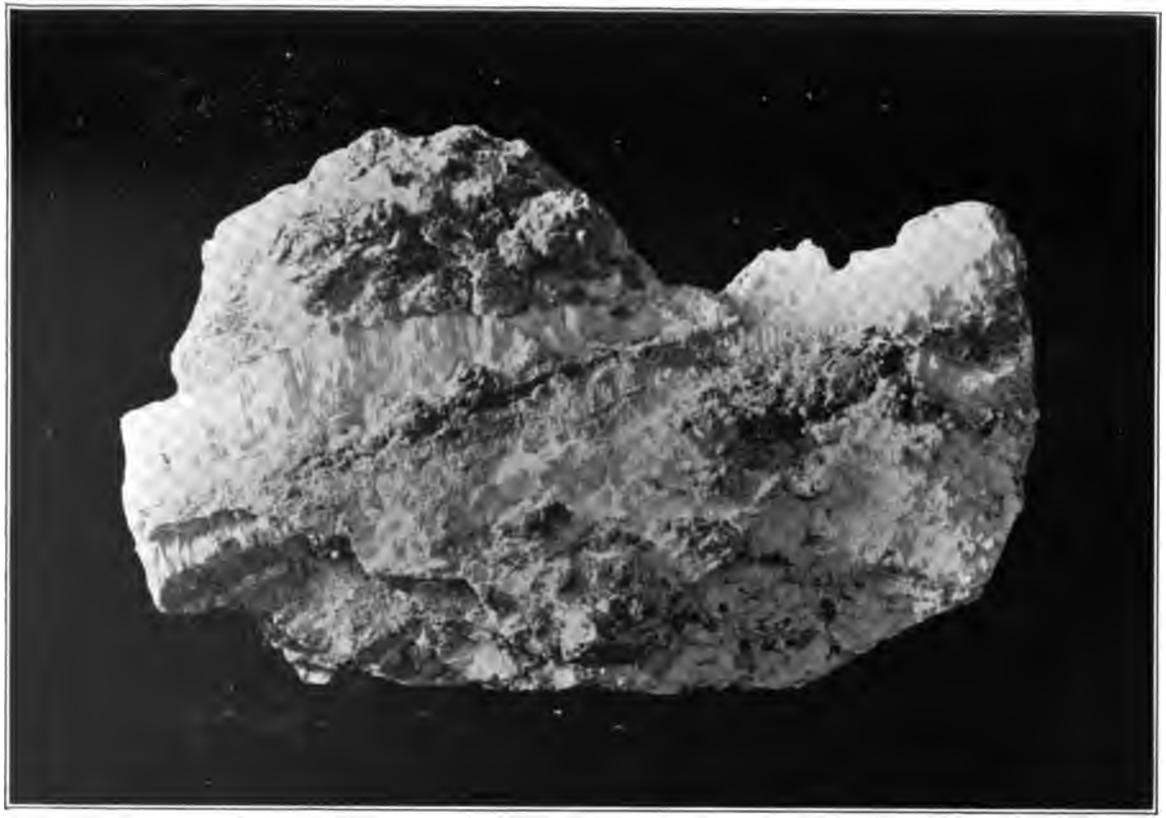


PLATE XXVII: Melanterite, Hayward.
(⅔ natural size.)

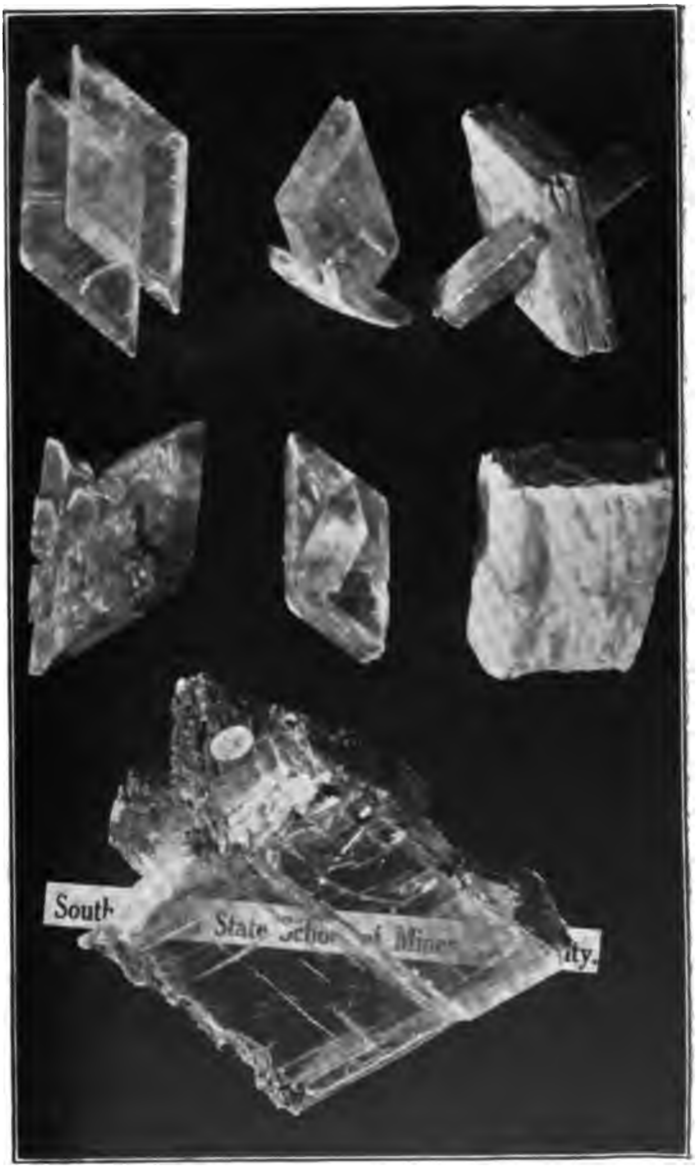


PLATE XXVIII: Selenite Crystals
from near Hermosa, Mass
from Inyan Kara.
(⅓ natural size.)

as that would fall in the realm of economic geology rather than mineralogy.

NATURAL GAS.

This is a mixture of a series of gases, chief of which is methane ($C H_4$). It is usually stored up under pressure under impervious layers of rocks and in the top of dome-like swells or folds called anticlines. It is usually intimately associated with oil and asphalt-like materials and in common with these is a decomposition product of plant or animal remains, which were buried with the sedimentary rocks, and which being preserved from rapid decay, were subjected to distillation partially accellerated by heat and pressure.

Natural gas has been found in a number of places in the Black Hills, though at present there are no commercial wells.

NATURAL OIL.

Oil or petroleum is a liquid hydrocarbon of very variable composition. In keeping with this, its physical characteristics vary decidedly, thus we can get all gradations from pale yellow to an almost black color, with dark brown the most common shade. In consistency it varies from very mobile to thick visceous and tarry fluids.

In the Black Hills it is usually associated with natural gas and is found in the sandstone of the Minnelusa and Graneros formation on the western border of the Black Hills.

ASPHALTUM.

By the natural distillation of the lighter and more volatile constituents of the natural oils a heavy tarry or asphalt like residue is often left behind. This is frequently quite hard, has a fine conchoidal fracture, and a dark brown to black color, and resinous luster. When ignited it burns readily with a long yellow smoky flame and a pitchy odor.

In limited amounts it is frequently associated with oil. It also occurs in small amounts as a filling of pores in sandstone in places where the lighter hydrocarbons have been completely distilled off.

COAL.

Lignite is the only representative of the coals found in the Black Hills region. It is of rare occurrence in the Lakota formation and of great importance in the Laramie formation, especially northwest and west of the Black Hills.

These coals are usually pitchy black and shiny in color, but may also be brown and dull. They have a conchoidal fracture and a brown streak, are very brittle and burn with a long yellow and smoky flame, yielding a quick fire. Their specific gravity is usually below 1.25.

Lignite marks the first step in the metamorphism of pure vegetable matter such as peat into coal. Hence its close resemblance to cellulose, the vegetable tissue, in low specific gravity, high content of volatile hydrocarbons and water, and consequent low calorific power. By a decrease in the volatile hydrocarbons and a consequent increase in "fixed" carbon, the lignite changes into bituminous coals and these, in turn, into anthracite.

RETINITE.

Some of the Lignite from the Wyoming side of the Black Hills often shows inclusions of rounded and elongated lens-like masses of an amber-like resin. This is yellow to amber in color and has a resinous luster. It has a conchoidal cleavage. The hardness is about 3, and the specific gravity very slightly above that of water. It burns very readily with a long smoky flame and pitchy odor.

ECONOMIC CLASSIFICATION OF BLACK HILLS MINERALS.

(The following list includes the minerals which carry fair amounts of each particular element. Those especially important as ores, though not necessarily so in the Black Hills, are capitalized.)

1. *Gold Group*: GOLD, PYRITE, ARSENOPYRITE, SYLVANITE.

2. *Silver Group*: SILVER, argentite, cerargyrite, embolite, pyrargyrite, GALENITE (argentiferous).

3. *Mercury Group*: CINNABAR.

4. *Copper Group*: COPPER, BORNITE, CHALCOCITE, CHALCOPYRITE, covellite, tetrahedrite, stannite, atacamite, cuprite, melaconite, olivenite, torbernite, chalcanthite, MALACHITE, AZURITE, CHRYSOCOLLA, cuprocassiterite.

5. *Zinc Group*: SPHALERITE, ZINCITE, SMITHSONITE, CALAMINE, WILLEMITE (?), kehoite, goslarite.

6. *Lead Group*: GALENITE, altaite, JAMESONITE, meneghinite, boulangerite, geocronite, semseyite, matlockite, plattnerite, CERUSSITE, ANGLESITE, vanadinite, wulfenite, PYROMORPHITE.

7. *Cadmium Group*: Greenockite.

8. *Tin Group*: CASSITERITE, stannite, cuprocassiterite.

9. *Titanium Group*: RUTILE, ilmenite, tapiolite, struverite, titanite.

10. *Cobalt and Nickel Group*: Niccolite, PYRRHOTITE.

11. *Uranium Group*: Autunite, torbernite, uranocircite, URANINITE, uraconite.

12. *Iron Group*: Iron, bornite, chalcopyrite, pyrrhotite, pyrite, marcasite, arsenopyrite, loellingite, leucopyrite, stannite, HEMATITE, ilmenite, MAGNETITE, LIMONITE, SIDERITE, ankerite, columbite, tantalite, triphylite, soda-triphylite, triplite, lithiophylite, griphite, dufrenite, vivianite, purpurite, cacoxenite, scorodite, diadochite, arsenostrengite, wolframite, ferberite, melanterite, amarantite,

jarosite, halotrichite.

13. *Aluminum Group*: Spinel, CORUNDUM, amblygonite, kalinite, pickeringite, amblygonite, andalusite.

14. *Beryllium Group*: Beryl.

15. *Cerium, Lanthanum, Didymium Group*: MONAZITE, fluocerite.

16. *Magnesium Group*: Spinel, dolomite, MAGNESITE.

17. *Calcium Group*: Fluorite, CALCITE, dolomite ~~columite~~, ankerite, ARAGONITE, scheelite, anhydrite, GYPSUM, autunite.

18. *Barium and Strontium Group*: BARITE, CELESTITE, uranocircite.

19. *Soda, Potash and Lithia Group*: HALITE, AMBLYGONITE, triphylite, LITHIOPHYLITE, lepidolite, FELDSPARS, SPODUMENE, kalinite, jarosite, glauconite.

20. *Arsenic Group*: ARSENOPYRITE, leucopyrite, loellingite, arsenolite, claudetite, niccolite, olivenite, arsenostrengite.

21. *Antimony Group*: STIBNITE, cervantite, bindheimite, JAMESONITE, meneghinite, semseyite, geocronite.

22. *Bismuth Group*: BISMUTH, BISMUTHINITE. tetradymite, bismite, bismutite.

23. *Tellurium Group*: Sylvanite, tetradymite, tellurite.

24. *Tungsten Group*: WOLFRAMITE, FERBERITE, HUEBNERITE, SCHEELITE.

25. *Niobium-Tantalum Group*: COLUMBITE, TANTALITE, tapiolite, struverite.

26. *Sulphur Group*: SULPHUR, PYRITE, PYRRHOTITE, sphalerite, galenite, chalcopyrite, etc.

27. *Carbon Group*: GRAPHITE.

28. *Molybdenum Group*: MOLYBDENITE, wulfenite, molybdite.

29. *Manganese Group*: PYROLUSITE, MANGANITE, WAD, triphylite, triplite, griphite, purpurite, HUEBNERITE, WOLFRAMITE.

30. *Vanadium Group*: Vanadinite.

BIBLIOGRAPHY OF BLACK HILLS MINERALOGY.

1880.

1. **Jenney,** W. P. Mineral resources of the Black Hills of Dakota. U. S. Powell Survey: Report of the Black Hills of Dakota, pp. 233-324, 1880.

This is the first systematic discussion of the ore deposits of the Black Hills. The occurrence of gold ores is especially emphasized.

2. **Caswell,** J. H. Microscopical Petrography of the Black Hills of Dakota. In the same volume as above, pp. 471-530.

In the two papers cited above the following minerals are mentioned and incidentally described: Apatite, augite, arsenopyrite, biotite, brown mica, calcite, chalcedony, cyanite, feldspar, ex. orthoclase, plagioclase (?), oligoclase, fossil wood, galena, garnet, glauconite, graphite, gold, gypsum, hematite, jasper, hornblende, limonite, magnetite, muscovite, nephelite, noselite, opal, pyrite, pyrrhotite, rose quartz, serpentine, sanidine, siderite, staurolite, titanite, tourmaline.

1882.

3. **Deveraux, Walter** B. The Occurrence of Gold in the Potsdam Formation, Black Hills, S. D. Am. Inst. Min. Eng., Trans. Vol. X., pp. 465-475, 1882.

Gives a thorough discussion of the so-called cement ores and upholds their mechanical origin. Cites analyses of the gold from the Homestake, Highland, Terror, Deadwood and De Smet ore bodies and from cement ores. Also mentions the occurrence of gold, silver, cerargyrite, and copper minerals on Bald Mountain, and that argentiferous lead ores occur elsewhere in rocks of the same age.

1884.

4. **Blake,** W. P. Cassiterite, Spodumene and Beryl in the Black Hills, Dakota. Am. Jour. Sci., 3rd series, Vol. 26, pp. 235.

Mentions the occurrence and associations of these minerals with mica and feldspar in the Etta Knob.

5. Williams, Albert, Jr. Mineral Resources of the United States. U. S. Geol. Survey, Min. Res., 1883, pp. 813.

Cites on page 754 the following economic products from the Black Hills reported by Whitman Cross; galenite, gold, muscovite, auriferous pyrite, coal and gypsum, and mentions some of their associated minerals, and the localities of their occurrence.

1884.

6. Blake, W. P. Columbite in the Black Hills of Dakota. Am. Jour. Sci., 3rd series, Vol. XXVIII., pp. 340-341.

This is the first notice of the occurrence of columbite with cassiterite, albite, and mica, at the Etta and Ingersoll mine, east of Harney Peak. Mentions their crystal form and blow pipe reactions.

7. Schaeffer, Charles A. A New Tantalite Locality. Am. Jour. Sci., 3rd series, vol. XXVIII., p. 430.

Mentions the occurrence of tantalite at the Etta mine, and gives properties and chemical analysis. Mentions also the occurrence of scorodite, leucopyrite, and olivenite from the same locality.

8. Schaeffer, Charles A. Note on Tantalite and Other Minerals Accompanying the Tin Ore in the Black Hills. Am. Inst. Min. Eng., Trans., vol. XIII., pp. 231-233.

This is the first identification of tantalite, together with an analysis. As associated minerals scorodite, and olivenite are also mentioned.

1885.

9. Blake, W. P. Spodumene Crystals of Gigantic Size. Note in Am. Jour. Sci., vol. XXIX., 3rd series, p. 71.

Mentions large spodumene crystals from the Etta tin mine, near Keystone.

10. Stillwell, L. W. In a note in Am. Jour. Sci., vol. XXX., 1885, p. 82.

Mentions the occurrence of pitchblende(uraninite) and uranium mica (probably autunite) on Bald Mountain.

11. **Blake, W. P.** Tin Ore Veins in the Black Hills. Am. Inst. Min. Eng., Trans., vol. XIII., pp. 691-696.

Discusses the character of the tin ores, their occurrence, relation to the surrounding rocks, and origin. Mentions as associated minerals, among others, albite, spodumene, tourmaline, indicolite, apatite, heterosite, triphyllite, leucopyrite, tantalite, columbite and a copper sulphide.

12. **Blake, W. P.** Tin Ores in the Black Hills of Dakota. U. S. G. S. Mineral Resources 1883-84, 602-613.

Discusses briefly the geology and mineralogy of the tin deposits. Gives especial attention to the description of the Etta Knob.

13. **Blake, W. P.** Columbite and Tantalite in the Black Hills of Dakota. Am. Inst. Min. Eng., Trans., vol. XIII., pp. 696-697.

Mentions the occurrence of these minerals in greisen, and describes one mass over two thousand pounds in weight from the Ingersoll claim.

14. **Emmons, Samuel F.** Geological sketch of the Black Hills of Dakota. Tenth Census, vol: XIII., Precious Metals, pp. 89-94.

Contains a summary of the geological information regarding the Black Hills up to this time. The deposits of gold and silver and their mineral associations are especially emphasized. The article concludes with a list of the different mines of the Hills and notes on their rocks, ores, and gangue minerals in a tabulated form.

1888.

15. **Carpenter, Franklin R.** "Preliminary report of the South Dakota State School of Mines upon the Geology, Mineral Resources, and Mills of the Black Hills of Dakota," map, 1888.

Treats of the occurrence of gold, silver, copper, nickel, tin, building stones, clay and limestone. Discusses more especially the distribution and association of the gold and cassiterite. Analyses of the tin ores are given.

16. **Crosby, W. O.** Geology of the Black Hills of Da-

kota. Boston Soc. Nat'l Hist. Proc., vol. XXIII., pp. 488-517, vol. XXIV., p. 11, 1888.

Summarizes previous work of Newton, Jenney. Discusses the rocks of the Hills, mentioning their common minerals, among others hydromica, specular hematite. Arrives at the conclusion that the granite of Harney Peak is not true erruptive in origin. Briefly calls attention to the contact ore deposits of the Ruby basin and their origin.

17. Crosby, W. O. "Quartzites and Siliceous Concretions." Sci. Am. Supplement, vol. II., pp. 10466-10468, also Tech. Quarterly 1888.

18. Carpenter, Franklin R. "Ore Deposits of the Black Hills of Dakota." Am. Inst. Min. Eng., Trans., vol. XVII., pp. 570-598.

A discussion of the geology of the gold, tin, copper and nickel deposits in the Black Hills. Includes a classification of.economic deposits, and cites analyses of gold and cassiterite, columbite and tantalite.

1890.

19. Van Hise, C. R. "The Pre-cambrian Rocks of the Black Hills." Geol. Soc. Am., Bull., vol. I., pp. 203-244, plates 4-5, 1890.

This important paper is more especially concerned with the rocks of the central and southern Black Hills, with their structure, petrography and origin. The metamorphic processes leading to the formation of the slates and schists, and the mineralogical changes resulting are emphasized. The garnets, staurolite and tourmaline are described briefly.

20. Headden, William P. Columbite and Tantalite from the Black Hills. Col. Sci. Soc., Proc., vol. III., pt. III., pp. 323-34 . Same paper in Am. Jour. Sci. for 1901, which see.

21. Headden, William P. Notes on the discovery and occurrences of tin ore in the Black Hills, S. D. Col. Sci. Soc., Proc., vol. III., pt. III., pp. 347-350.

Contains notes on the general geology of the district. Notes that tin was first identified by Dr. Richard Pearce of

Denver in 1876, in the form of stream tin from the Northern Hills. Later (1877) it was also discovered on Elk Gulch in the Southern Hills.

22. **Clark, Frank** W. Reports of the Work Done in the Division of Chemistry and Physics. U. S. Geol. Survey, Bull. No. 60, p. 174.

Cites an analysis of triplite on pages 135-136 from a tin mine in the Hills.

23. **Chance, H. M.** The Resources of the Black Hills and the Big Horn Country, Wyoming. Am. Inst. Min. Eng., Trans., vol. XIX., pp. 49-58.

Notes the occurrence of coal, oil, and gas, west of the Hills.

1891.

24. **Headden, W. P.** Columbite and Tantalite from the Black Hills of South Dakota. Am. Jour. Sci., 3rd series, vol. XLI., pp. 89-102, 1891. Also in the Proceedings of the Col. Sci. Soc. for 1890.

Contains a thorough description of the occurrence and associations of columbite and tantalite in addition to an extensive series of analyses. Also describes a manganiferous columbite.

25. **Headden, W. P.** A New Phosphate from the Black Hills of South Dakota. Am. Jour. Sci., 3rd series, vol. XLI., pp. 415-416, Fig. 3.

Describes from the Black Hills a new mineral "griphite," found in the Riverton Lode near Harney City. Cites five chemical analyses of the same. Also mentions that associated with beryl and spodumene he finds a new phosphate near triphyllite in composition and gives two analyses of the same.

26. **Headden, W. P.** and **Pirrson, L. V.** On Black Rutile from the Black Hills. Am. Jour. Sci., 3rd series, vol. XLI., pp. 249-250, Fig. 1.

In a brief note attention is called to the rutile from the Harney Peak district. Two analyses are given, as are also a few well defined crystal forms and their angles.

27. **Blake, W. P.** Columbite of the Black Hills, South

Dakota. Am. Jour. Sci., 3rd series, vol. XLI., pp. 403-405, 1891.

Contains a few notes and summary of a number of crystal forms identified by Prof. S. L. Penfield.

28. Clarke, Frank W. Report of the Work Done in the Division of Chemistry and Physics. U. S. Geol. Survey, Bull. No. 78, pp. 129.

Gives an analysis of liebnerite from the Brown tin mine.

29. Thomas, Josiah. Harney Peak Tin Mines. Engineering and Mining Journal, vol. 58, pp. 512-14, 536.

This is Mr. Thomas' report based on a ten days' examination, to the Harney Peak Consolidated Tin Co. A number of different claims are briefly described.

1892.

30. Claypole, E. W. The Tin Islands of the Northwest. Am. Geol., vol. IX., pp. 228-236, 1898.

Gives observations on the Southern Hills. Considers the tin deposits as veins of segregations. Gives a brief summary of the stratigraphy of the Black Hills, and a few statements about the occurrence of tin ore.

31. Ulke, Titus. A contribution to the Geology of the Dakota Tin Mines. Eng. Min. Jour., vol. III., p. 547, 1892.

Classifies ore occurrences in ten phases according to mineral composition. Discusses their structure and calls attention to the coarseness of their crystallization. Mentions triplite, graphite and wolframite as associated minerals. Discusses the origin of the ores and cites points favoring the theory that ores are igneous dikes.

1893.

32. Headden, W. P. Stannite and some of Its Alteration Products from the Black Hills. Am. Jour. Sci., 3rd series, vol. XLV., pp. 105-110.

Mentions the occurrences of stannite near Keystone, gives analyses of material from the Etta and the Peerless mine which appears to be cupro-cassiterite.

33. Knight, W. C. A Catalog of Wyoming Minerals. Wyo. Exper. Station, Bull. 14, 201-211.

Gives a list of localities of occurrences of the minerals of Wyoming. Many from Crook, Converse and Custer counties are included.

34. Headden, W. P. Kehoite, a New Phosphate from Galena, Lawrence county, South Dakota. Am. Jour. Sci., 3rd series, vol. XLVI., pp. 22-24, 1893.

Mentions that associated with argentiferous galena, sphalerite, and pyrite occurs a new mineral to which he applies the name kehoite. Cites three analyses of the same. States also that jarosite occurs in the Buxton mine in Lawrence Co. and gives analyses.

35. Morse, A. J. Harney Peak Tin Mines. Engineering and Mining Journal, vol. 58, 463.

Refers to activity of Harney Peak Tin Co. Calls attention to the irregularity in the veins and dikes.

36. Ulke, Titus. A New Tin Mineral in the Black Hills. Am. Inst. Min. Eng., Trans., vol. XXI., pp. 240-241, 1893.

Discusses the new mineral cuprocassiterite. Notes its occurrence, association, and origin. Gives one analysis.

1894.

37. Pirrson, Louis V. On Some Phonolite Rocks from the Black Hills. Am. Jour. Sci., 3rd series, vol. XLVII., pp. 341-346, 1894.

Gives a petrographic discussion, with chemical analyses, of several rocks whose exact locality is unknown. Titanite, nephelite, ægerite, sodalite (?), calcite, and zeolitic material are mentioned. The optical properties of most of these minerals are given.

38. Todd, James E. A Preliminary Report on the Geology of South Dakota. S. D. Geol. Survey, Bull. No. 1, 172 pp. pl. I-V., Figs. 1 and 2, 1894.

This is a summary of the geology of South Dakota. Rocks and economic deposits are also described briefly.

1895.

39. Rolker, Chas. M. The Production of Tin in Various Parts of the World. U. S. Geol. Survey, 16th Ann. Report, vol. IV., pt. 3, pp. 458-538, 1895.

This is a summary of the tin producing districts of the world. On pages 530-535 a brief discussion of the tin districts of the Black Hills are given, especially those in the southern Hills. Most of the information is from previous articles. Several analyses of ores for tin are cited.

40. Weeks, Joseph D. Manganese. U. S. Geol. Survey, 16th Ann. Report, pt. III. Mineral Resources, pp. 389-457, 1895.

On page 423 calls attention to the production of manganese in Custer county and gives analysis.

41. Parker, Edward W. Gypsum. U. S. Geol. Survey, 16th Ann. Report, part IV. Mineral Resources.

Gives on page 664 the production of gypsum in the Black Hills, 1889-1891, 1893-1894.

42. Case, E. C. On the Mud and Sand Dikes of the White River Miocene. Am. Geo., vol. XV., pp. 248-254.

Discusses also the origin and occurrence of veins of chalcedony, frequently associated with calcite in the White River bad lands.

1896.

43. Van Hise, Charles R. Principles of North American Pre-Cambrian Geology. U. S. Geol. Survey, 16th Ann. Report, pp. 581-843, pls. CVIII-CXVI., Figs. 101-162, 1896.

Contains on pages 813-814 a brief summary of the so-called Algonkian rocks in the Black Hills. Also on pages 687 and 688 the origin of the granites of Harney Peak and the pegmatite is summarized. The information given is condensed from articles in the Bulletin of Geol. Soc. of America, 1891, by the same author.

1897.

44. Scott, Samuel. Map of the Black Hills of South Dakota and Wyoming, with Full Description of Their Mineral Resources, etc. Private publication, 40 pages and map.

This useful little booklet, accompanied by a colored geological map, is a summary of Black Hills geology and mineralogy for the layman. The rocks and minerals of the Black Hills are listed and briefly described, although the list is not complete nor fully reliable as to the occurrence of different species. Closes with a description of a few points of interest to tourists. In all ninety minerals are mentioned.

45. Frazer, Persifor. Notes on the Northern Black Hills. Am. Inst. Min. Eng., Trans., vol. XXVII., pp. 204-231, 1897.

Contains a brief summary of previous work and notes on gold and associated minerals as determined by panning and subsequent microscopic examination, more especially from the vicinity of Galena. Among others, diopside, beryl, argentite (?), serpentine (?), pyrrhotite, opal, rutile, barite (?). There is also included a series of analyses of rocks made by various analysts in the chemical laboratory of the University of Pennsylvania.

46. Smith, Frank C. The Occurrence and Behavior of Tellurium in Gold Ores, More Particularly with Reference to the Potsdam Gold Ores of the Black Hills, South Dakota. Am. Inst. Min. Eng., Trans., vol. XXVI., pp. 485-515, Figs. II, 1897.

Discusses methods of analysis and cites a number of the so-called siliceous ore. Believes that tellurium is present as sylvanite.

47. Blake, W. P. Gold in Granite and Plutonic Rock. Am. Inst. Min. Eng., Trans., vol. XXVI., pp. 290-298, 1907. Abstract in Min. and Sci. Press, vol. LXXIII., p. 296, 1896.

Calls attention to the occurrence of gold in "granitic" schists of the Pre-cambrian age, in the Homestake mine.

1898.

48. Barbour, E. H. Barites of Nebraska and the Bad Lands. Neb. State Hist. Soc., Proc. Coll., 2nd series, vol. II., pp. 265-268, 3 pls., 1 fig., 1898.

49. Todd, James E. Section along Rapid Creek, from Rapid City westward. S. D. Geol. Survey, Bull. 2, 27-40, 1 map.

Mentions the occurrence of gold, iron ore, asbestos and gypsum.

50. SMITH, FRANK C. The Potsdam Gold Ores of the Black Hills of South Dakota. Am. Inst. Min. Eng., Trans., vol. XXVII., pp. 404-428, 1898.

Discusses briefly the geology of the northern Hills. Emphasizes the gold ores of the Cambrian and Carboniferous. Gives analyses of several ores.

51. TODD, JAMES EDWARD. A Reconnaissance into Northwestern South Dakota. S. D. Geol. Survey, Bull. No. 2, pp. 43-68, pls. I, V-X. 1898.

This is especially devoted to a study of lignite deposits; analyses are given.

52. TODD, JAMES EDWARD. The Exploration of the White River Bad Lands in 1896. S. D. Geol. Survey, Bull. No. 2, pp. 117-135, Pls. XII-XV.

Mentions the occurrence of satin spar, barite and sapphirine on page 132.

53. DILLER, JOSEPH S. The Educational Series of Rock Specimens, Collected and Distributed by the U. S. Geological Survey. U. S.Geol. Survey, Bull. No. 150, 400 pp.

Contains a description of phonolite by Mr. Whitman Cross, and of tourmaline-biotite schist by Mr. W. S. Bailey.

53a. FARRINGTON, O. C. New Mineral Occurrences. Field Columbian Museum Publication, Geol. series, vol. 1, No. 7, 1900.

Includes a brief description of the characteristics and forms of Golden Calcite from the Cheyenne River county.

1899.

54. HOLMES, J. A. Mica Deposits in the United States. U. S. Geol. Survey, 20th Ann. Report, vol. VI., Min. Res., pp. 691-707.

Discusses among others, the mica industry of the Black Hills from an economic standpoint, noting origin, occurrence, extent, value and associated minerals.

55. IRVING, JOHN D. A Contribution to the Geology of the Northern Black Hills. N. Y. Acad. Sci., Annals, vol. XII., pp. 187-340, pls. V-XVI., figs. 5-20, 1899.

This is a thorough discussion of the geology of the Black Hills, slightly west of Deadwood. Thorough petrographic description of different rocks are given and their relationship is discussed. Aegerite, microcline, anorthoclase, nephelite, noselite, hauynite, titanite, melanite, zoisite, ilmenite, are incidentally described among others. Discusses fully on page 270 a mineral formerly identified as leucite, which is probably noselite. Concludes with a description of the ore bodies and their origin.

56. O'HARRA, C. C., and FORSYTH, A. Notes on the Geology and Mineral Deposits of a Portion of the Southern Black Hills. S. D. School of Mines, Bull. 41, pp., 11 figs., 1899.

Discusses especially a small portion in the north central part of Custer County. The rocks and their minerals are well described. Discusses the occurrence of melanterite and amarantite (?). Gold veins, argentiferous galena, graphite, mica and spodumene are briefly noted.

1900.

57. CHANCE, H. M. Gold Ores of the Black Hills, South Dakota. Eng. Min. Jour., vol. LXIX., pp. 227-228 ($\frac{1}{2}$ p.) 1900.

Calls attention to the two classes of ores, the free milling, and the siliceous, and notes their distribution.

58. HOVEY, E. O. The Wind Cave of South Dakota. Sci. Am. Suppl., vol. XLIX., pp. 20458-20459, 1900.

59. PENFIELD, S. L., and FORD, W. E. Siliceous Calcites from the Bad Lands, Washington county, South Dakota. Am. Jour. Sci., 4th series, vol. IX., pp. 352-354, pl. 1, figs. 1-4, 1900.

Mentions a new form of sand crystal from the White River Bad Lands, and discusses their origin.

60. BARRELL, ROBERT W. The Bear Butte Mineral Formation (Black Hills, South Dakota). Mines and Minerals, vol. XX., pp. 512-514, 1 fig., 1900.

Discusses the gold ores and their occurrence in the Deadwood formation, and relation to igneous rocks.

1901.

61. Barbour, E. H. Sand Crystals and Their Relation to Certain Concretionary Forms. Geol. Soc. Am., Bull., vol. XII., pp. 165-172, 6 pls., 1901.

Gives a full description of the occurrence, distribution, character, and origin of sand-calcite crystals near Devil Hill, together with analyses, and a list of some crystal angles.

62. O'Harra, C. C. Black Hills Ore Deposits. Int. Min. Cong., 4th session, pp. 97-100, 1901.

Mainly a condensation of the author's work on "The Mineral Wealth of the Black Hills."

63. Warren, C. H. Mineralogical Notes. Am. Jour. Sci., 4th series, vol. II., pp. 369-373.

Contains on page 372 a description of crystals of wolframite from the Black Hills giving a tabulation of the forms and crystal angles. 1902.

64. Barbour, E. H., and Fisher, C. A. A New Form of Calcite-sand Crystal. Am. Jour. Sci., 4th series, vol. 14, pp. 451-454, 4 figs, 1902.

Mentions sand-calcite crystals made up of combinations of rhombohedra from the Goshen Hole region. Also gives analyses of these and also of specimens from Devils Hill, Washington County, S. D. Summarize the geologic and geographic distribution of sand crystals.

65. O'Harra, C. C. The Mineral Wealth of the Black Hills (South Dakota). So. Dak. School of Mines, Bull. No. 6, Dept. Geology, pp. 88, 22 pls., 1902.

This bulletin contains a summary of the geological knowledge regarding Black Hills ore deposits up to this time, together with much new information. Deposits and occurrences of the following are fully discussed: Gold, copper, iron, manganese, silver and lead, tin, tungsten, graphite, mica and spodumene, the occurrence of jamesonite, bismuth, cinnabar, nickel, and uranium minerals is also briefly mentioned. Describes the association of different ores and on pp. 67-68 gives a complete list of minerals found in the tin deposits of the Black Hills, among which are grossular-

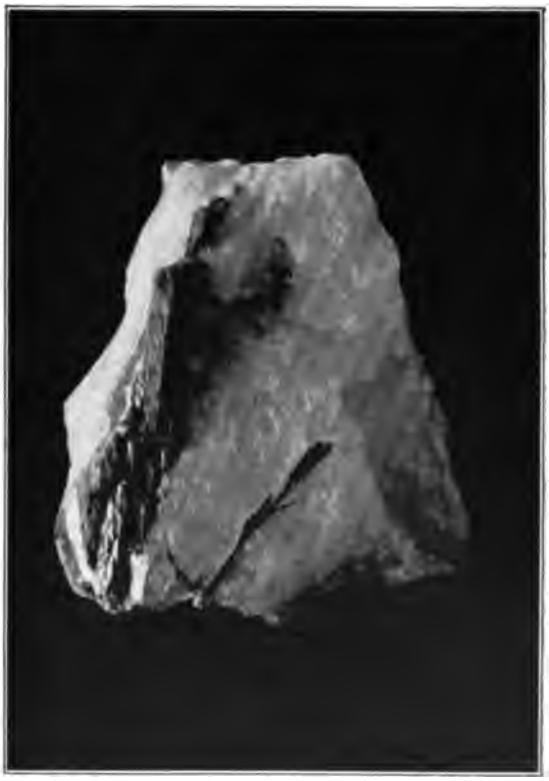


PLATE XXIX: Wolframite,
Hill City.
(⅔ natural size.)

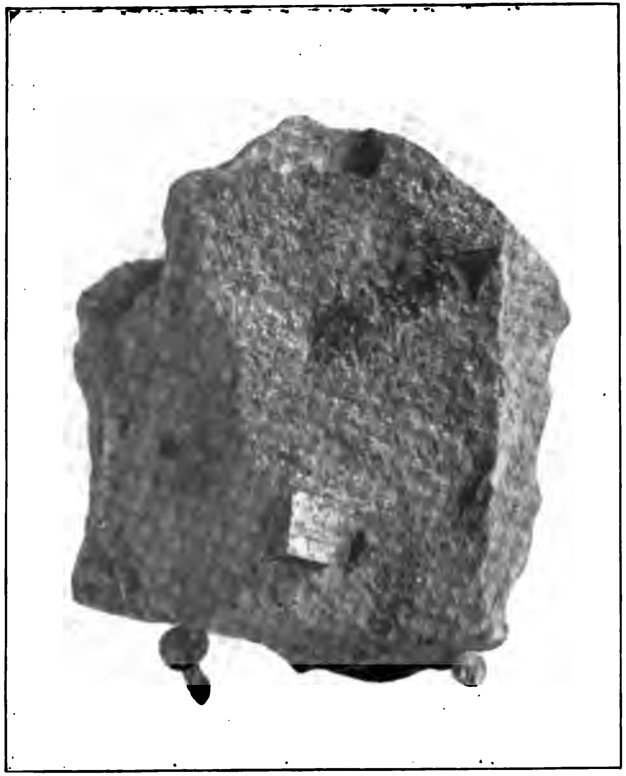
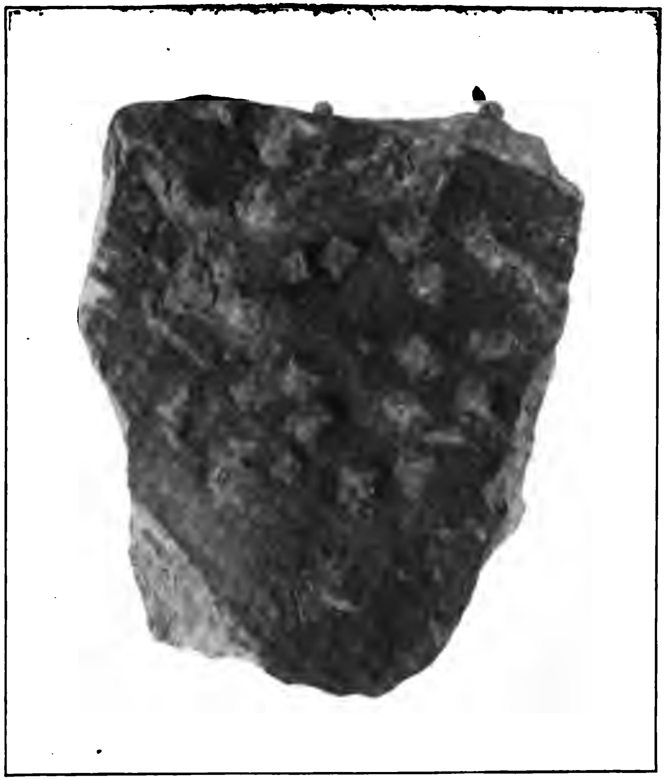


PLATE XXX: Pseudomorph.
Limonite after Pyrite.



Sandstone after Halite.

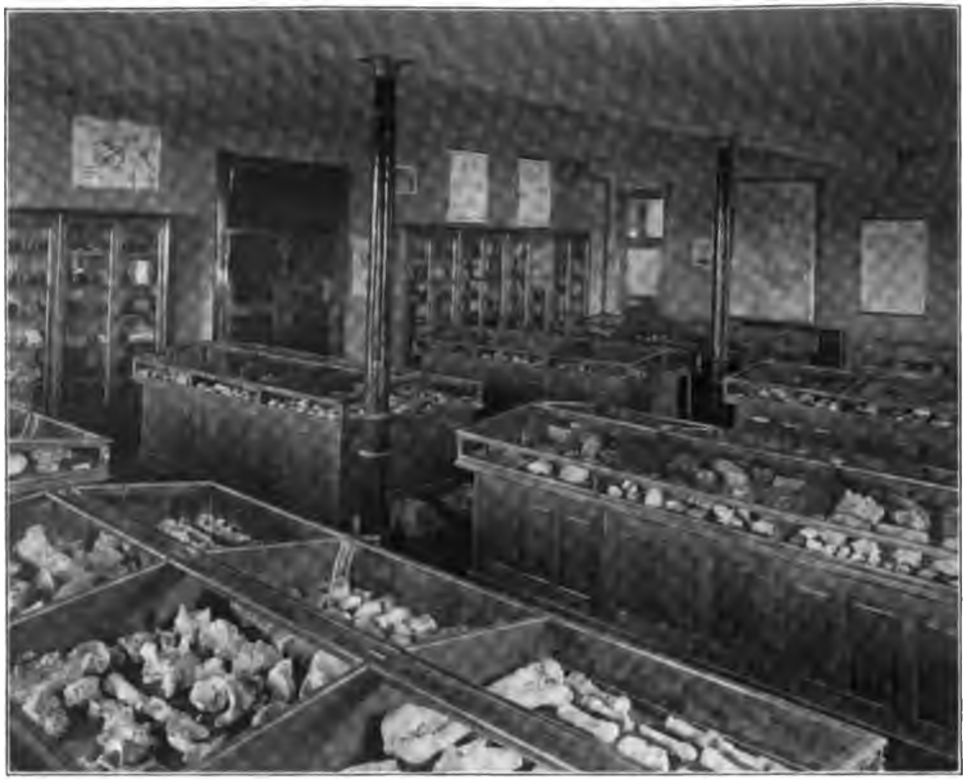


PLATE XXXI: Geological and Mineralogical Museum
State School of Mines, Rapid City.

ite, ilmenite, liebnerite, petalite, scheelite, sphene, spinel and zircon. Many analyses are given.

66. DARTON, N. H. Oelrichs Folio. U. S. Geol. Survey, folio No. 85.

Mentions and describes the occurrence of gypsum.

67. IRVING, JOHN DUERR. Some Recently Exploited Deposits of Wolframite in the Black Hills of South Dakota. Am. Inst. Min. Eng., Trans., vol. XXXI., pp. 653-695, 1 fig., 1 map, 1902.

Describes the occurrence of wolframite, its character, its associations and probable origin, and cites analyses by Mr. W. F. Hillebrand. Gives some generalizations about the occurrence of wolframite in conclusion.

68. FORSYTH, ALEXANDER. "Wolframite in the Black Hills." Discussion of paper by J. D. Irving. Am. Inst. Min. Eng., Trans., vol. XXXI., pp. 1024-1025, 1902.

Calls attention to the occurrence of free gold intimately associated with the wolframite in the Harrison mine near Lead.

1903.

69. BLATCHFORD, JOHN. The Potsdam Formation of Bald Mountain District (South Dakota). Min. and Sci. Press, vol. LXXXVII., pp. 167, 1903.

Describes the occurrence of the gold ores in the Deadwood formation.

1904.

70. BLATCHFORD, JOHN. The Bald Mountain District. Mines and Minerals, vol. 24, p. 394, 1904.

Same articles as above, but somewhat extended.

71. GARRISON F. LYNWOOD. Tin in the United States. Eng. Min. Jour., vol. LXXVIII., p. 830, 1904.

Gives a brief summary of the tin occurrence in the Black Hills.

72. O'HARRA, C. C. The Geology and Mineralogy of the Black Hills region. Black Hills Mining Men's Asso., pp. 119-127, 1904. Am. Min. Cong., 6th Ann. session, Proc. pp. 87-93, 1904.

In the main a summary of No. 65.

73. Hovey, E. O. The Crystal Cave of South Dakota. Sci. Am. Suppl., vol. LVII., pp. 23657-23658, 4 figs., 1904. Not available.

74. Irving, John D., Emmons, S. F., and Jagger, T. A. Economic Resources of the Northern Black Hills. U. S. Geol. Survey, P. P. No. 26, pp. 222, pls. 20, figs. 16, 1904.

The region in the vicinity of Lead and Deadwood is especially discussed. This is to quite an extent an elaboration of Dr. Irving's previous paper. The ore and gangue minerals of the various mines are separately mentioned and their relationship discussed. Contains full descriptions of the important mines and their ore bodies.

75. Irving, John D. The Ore Deposits of the Northern Black Hills. Mg. Rep., vol. L., pp. 430-431, 1904.

Practically an abstract of the article below.

76. Irving, John D. The Ore Deposits of the Northern Black Hills. .U S. Geol. Survey, Bull. No. 225, pp. 123-140, 1904. Am. Min. Cong., 6th Ann. session, Proc., pp. 38-51, 1904.

Brief description of ore deposits mostly condensed from U. S. Geol. Survey, folio 26, by the same author.

77. Darton, H. N. Newcastle Folio. U. S. Geol. Survey, folio No. 107.

Coal, petroleum, gypsum, salt and bentonite are discussed under economic products.

78. Darton, H. N., and Smith, W. S. Tangier. Edgemont Folio. U. S. Geol. Survey, folio No. 108.

Coal and gypsum are discussed among others.

79. Darton, H. N. Gypsum Deposits of South Dakota. U. S. Geol. Survey, Bull. No. 223, pp. 76-78, 1 pl., 2 figs., 1904.

Calls attention to the occurrence of gypsum around the Black Hills, discusses amount and gives an analysis by Dr. Steiger.

80. Simmons, Jesse. Tungsten Ores in the Black Hills. Mg. Rep., vol. 50, pp. 217-218, 1904.

Discusses their origin and occurrence.

1905.

81. Storms, W. H. The Golden West Mine, Pennington County, South Dakota. Min. & Sci. Press., vol. XCI., p. 257, 1 fig., 1905.

Describes the occurrence of the gold deposits.

82. Headden, W. P. Mineralogical Notes. Colo. Sci. Soc., Proc., vol. 8, pp. 53-70, 1905.

Contains among others a description and analysis of columbite.

83. Hess, F. L., and Graton, L. C. The Occurrence and Distribution of Tin. U. S. Geol. Survey, Bull. No. 260, pp. 161-187, 1905.

Contains a note as to the occurrence of tin in the Black Hills region.

84. Darton, H. N. Sundance Folio. U. S. Geol. Survey, folio No. 127.

W. S. Tangier Smith describes incidentally with igneous rocks their minerals on pages 4-8. Mentions occurrence of tourmaline, cassiterites, microcline and muscovite in pegmatite near Nigger Hill. Microperthite, nephelite, noselite, topaz, melanite, orthoclase and muscovite in pseudomorphs after leucite, analcite, natrolite, augite, andesine and ilmenite are mentioned among others.

85. Darton, H. N., and O'Harra, C. C. Aladdin Folio. U. S. Geol. Survey, folio No. 128.

Contains on pages 4 and 5 descriptions of igneous rocks by W. S. Tangier Smith. Gypsum is mentioned on page 8.

1906.

86. Headden, W. P. Mineralogical Notes III. Colo. Sci. Soc., Proc., vol. VIII., pp. 167-182, 1906. Describes cassiterite, jamesonite, meneghite, huebnerite, wolframite, and tapiolite and cites analyses. This article is reviewed in Jour. Am. Chem. Soc., November, 1906.

87. Carpenter, Franklin R. Tin in the Black Hills, South Dakota. Min. World, vol. XXV., No. 20, pp. 600-601, 1 fig., 1906.

88. Pratt, Joseph Hyde. The Cement Gold Ores of

Deadwood, Black Hills, South Dakota. Elisha Mitchell Sci. Soc., Jour., vol. XXII., No. 1, pp. 23-27, 1906.

Discusses the occurrence, distribution, thickness of the gold bearing portion of the Deadwood formation.

89. Sadtler, Benjamin. Gold and Tin in the Northwest Black Hills. Min. World, vol. XXIV., No. 17, pp. 520-522, 5 figs., 1906.

90. Storms, W. H. The Black Hills of South Dakota. Min. World, vol. XXIV., pp. 242, 272-273, 303-304.

A brief description of the geology and ore deposits of the Black Hills.

91. Colles, George Wetmore. Mica and the Mica Industry. The Franklin Institute, Philadelphia, 1906.

Contains very brief mention only on pages 48, 62 and 99.

1907.

92. Schaller, Waldemar T. Mineralogical Notes. Am. Jour. Sci., 4th. series, vol. XXIV., pp. 152-158, 1907.

Describes the occurrence of purpurite near Hill City, gives analysis and sketch of crystal.

93. Fawns, S. Tin Deposits of the World. London, 1907.

Black Hills Tin deposits are only mentioned in the bibliography.

94. Darton, N. H., and O'Harra, C. C. Devils Tower Folio. U. S. Geol. Survey, folio No. 150.

Contains petrographic descriptions of igneous rocks by Prof. Albert Johannsen on page 6. Among other minerals, apatite, sericite, nephelite, zeolite (?), analcite, anorthoclase, diopside, and rutile are mentioned. Gypsum is discussed under economic products.

1909.

95. Coolidge, C. W., and Overpeck, L. S. The Iron Deposits of the Black Hills, South Dakota. Min. Science, vol. LX., pp. 319-321, 1909.

Discuss the occurrence of iron ores near Hayward, Iron Mountain, Hatmound, Rochford, and on Box Elder Creek. Analyses of each are given.

96. Hess, Frank L. Tin, Tungsten and Tantalum Deposits of South Dakota. U. S. Geol. Survey, Bull., 380, pp. 131-161, 1 fig., 1909.

A discussion of these minerals and their occurrence in the Black Hills. The more important claims are briefly discussed separately. Mentions finding chalcocite in the Etta mine. The mineral associations and origin of the three kinds of deposits are discussed.

97. Darton, N. H., and O'Harra, C. C. Belle Fourche Folio. U. S. Geol. Survey, folio No. 164, 1909.

Mentions on page 7 the occurrence of gypsum, coal and bentonite among other economic products.

98. Simmons, Jesse. Tin in the Black Hills of South Dakota. Min. World, vol. XXX., pp. 925-926, 1 fig., 1909.

Describes the geology of a number of different mines in the vicinity of Harney Peak.

99. Sterrett, Douglas B. Mica Deposits of South Dakota. U. S. Geol. Survey, Bull., 380, pp. 382,397, 4 figs., 1909.

Discusses the geology, occurrence, and origin of the mica-bearing pegmatites in the vicinity of Custer.

1910.

100. O'Harra, C. C. The Bad Land Formations of the Black Hills Region. So. Dak. School of Mines, Bull. No. 9, Dept. of Geology, pp. 152, pls. 50, figs. 20, map.

Contains a careful summary of the geology, mineralogy, and paleontology of the Bad Lands region. Mentions among others the occurrence and distribution of gold, agate, selenite, sand-calcite crystals and chalcedony.

1911.

101. Lincoln, Frances Church. Certain Natural Associations of Gold. Ec. Geol., vol. VI., pp.

Mentions incidentally the occurrence of gold in the placers, on Ragged Top, and pictures a specimen from the Homestake.

102. Irving, John D. Replace ment of Ore Bodies and the Criteria for Their Recognition. Ec. Geol., vol. VI., pp. 527-561, 619-669, 1911.

Discusses the occurrence of replacement deposits in various localities in the Black Hills. Has a number of illustrations showing various deposits of the Black Hills, and also photographs of thin sections of the Cambrian siliceous gold ore.

103. Sharwood, W. J. Analyses of Some Rocks and Minerals from the Homestake Mine, Lead, South Dakota. Ec. Geol., vol. VI., No. 8, pp. 729-789, figs. 411-426.

This is a valuable compilation of a series of analyses of the gold, minerals and rocks of the Homestake Mine, and a discussion of the significance of the same. The following minerals are listed, chlorite (with over 30% FeO), cummingtonite (new from the Hills), carbonates of calcium magnesia and iron (probably ankerite), black mica, andradite, pyrite, arsenopyrite, pyrrhotite, quartz, orthoclase, zircon, barite, hematite, magnetite, graphite, fluorite, galena, telluride of bismuth (tetradymite), copper, basic copper sulphate, black oxide of manganese, native gold.

104. Hess, F. L., and Wells, R. C. An Occurrence of Struverite. Am. Jour. Sci., 4th series, vol. XXXI., pp. 432, 1911.

This mineral occurs in considerable abundance in the pegmatite of the Etta claim. The mineral association is discussed, among others white beryl, and opal are mentioned. Gives forms and angles as determined by Schaller, Waldemar T. Chemical characteristics, analyses, and the relation of this mineral to the rutile group are discussed. Gives formula as $FeO(TaCb)_2O_5TiO_2$.

1912.

105. Ferguson, H. G., and Bateman, A. M. Geologic Features of Tin Deposits. Ec. Geol., vol. VII., No. 3, pp. 209-262, 1912.

This is a thorough summary and generalization of the occurrences, mineral relations, and methods of genesis of tin deposits in various parts of the world. The information incorporated regarding the Black Hills tin deposits is from articles by W. P. Blake, F. R. Carpenter, John D. Irving, F. L. Hess, and C. C. O'Harra.

106. SINGEWALD, JOSEPH T. Some Genetic Relations of Tin Deposits. Ec. Geol., vol. VII., No. 3, pp. 263-279, 1912.

Discusses the origin, among other tin deposits, of the Etta Knob and very briefly summarizes the conclusions of Beck, Bergeat, Beyschlag, Krusch, and Vogt, as expressed in their various treatises on economic geology and on deposits.

107. SCHALLER, WALDEMAR T. Mineralogical Notes. Series 2. U. S. Geol. Survey, Bull. 509, 1912.

In discussing the rutile group, analyses of tapiolite, struverite, and hutile from the Black Hills are quoted. Believes that the rutile described by Headden and Pirrson is really struverite.

108. U. S. GEOL. SURVEY. Miscellaneous Analyses of Coal Samples from Various Fields of the United States. Bulletin 471.

Contains on page 21 an analysis from Schnasse county, and on pp. 27 and 28 four analyses of sub-bituminous coal from Converse and Weston counties, Wyoming.

109. STONE, R. W. Coal Near the Black Hills. U. S. Geol. Survey, Bull. 499, pp. 64, figs. 8, pls. 7.

Discusses the general geology and the structure of the coal fields in the western portion of the Black Hills. Describes the physical properties and character of the coals, and gives a series of chemical analyses, and the results of a series of tests made at the U. S. G. S. Fuel testing plant at St. Louis. Calls attention to the fact that gold and silver occur in values up to $5.81 per ton in the coke made from the Cambria coal, as shown by tests by Hervy C. Beeler at Cambria, Wyo.

110. HILL, JAMES M. The Mining Districts of the Western United States. U. S. Geol. Survey, Bull. 507.

Gives a map of South Dakota on page 259, showing by symbols the distribution of the various mineral deposits.

This is accompanied by a brief list of statistics on pp. 251-261, of the kind of orè, chief shipping point, and important literature regarding each camp in the Black Hills.

111. ZIEGLER, VICTOR. A list of Black Hills Minerals. In O'Harra's Handbook of the Black Hills, Rapid City, S. D., September, 1913.

Contains a brief list of the minerals and rocks known from the Black Hills.

112. ZIEGLER, VICTOR. The Lithia Deposits of the Black Hills. Eng. & Min. Jour., Dec. 6, 1913.

A brief description of the more important lithia deposits. The occurrences of amblygonite, spodumene, triphylite, and lepidolite is discussed in detail.

113. ZIEGLER, VICTOR. "The Differentiation of a Granite Magma, as shown by the Paragenesis of the Minerals of Harney Peak Granite." Ec. Geol. IX No. 2, March, 1913.

Contains a table showing the paragenesis of the minerals of the central Black Hills. Mineral associations are listed under fourten headings. Seven phases in the differentiation of the Harney Peak granite are recognized in addition to the minerals of the older quartz veins, the different metamorphic rocks and the contact zones. The secondary minerals produced by weathering are also listed.

114. ZIEGLER, VICTOR. "The Mineral Resources of the Pegmatites of the Central Black Hills." Min. & Sci. Press, April, 1913.

The general geology of the central Black Hills is briefly discussed. The mineralogy of the pegmatites and the deposits of mica, tin, tungsten, lithia and rare metals receive particular attention.

TABLES FOR THE DETERMINATION OF BLACK HILLS MINERALS.

Directions for the Use of Tables.

There are three tables, arranged according to luster. Table A contains the minerals with metallic luster, Table B those minerals with non-metallic luster that possess a colored streak, and Table C the minerals with non-metallic luster and a white streak. Each table is then subdivided into sections horizontally according to hardness. The sections are further subdivided into vertical sections as follows:

Table A. The metallic minerals are arranged into five groups according to their color, subdivisions being provided for white, gray, yellow, red or blue and black.

Table B. The non-metallic minerals with colored streaks are sub-divided according to the color of their streak. Five subdivisions being established for yellow, brown, black or blue, red and green.

Table C. The non-metallic minerals with white streak are divided into six sections on the basis of structure and cleavage. An additional section is provided for those minerals possessing a taste.

To use the tables proceed as follows:

1st. Determine the luster of the mineral and turn to the proper table.

2nd. The second step in the use of any table is to determine the mineral's hardness, using finger nail, knife and glass plate as suggested.

3rd. The third step depends on the table used.

Table A. Follow down the vertical column, under the proper color until meeting the horizontal division indicating the proper hardness.

Table B. Follow the vertical column under the proper colored streak until meeting the horizontal division, indicating the correct hardness.

Table C. Determine the structure of the mineral, or see if it has a taste, and place in proper column and find intersection with horizontal division showing the hardness.

4th. The identity of the unknown mineral will now be restricted to the four or five located at the intersection of the vertical and horizontal subdivisions. A few characteristics of each mineral are given here. These may suffice for identification, but it will usually be found best to turn to the general discussion of each mineral when it will be possible to identify the mineral with some certainty.

An example may make this clear. We wish to determine the identity of the silky lustered pure white and fibrous mineral occurring as a lining on the walls of certain caves (such as Wind Cave for example). This is non-metallic in luster, and the color of its powder is white or colorless. We will hence turn to Table C. The mineral exceeds in hardness the finger nail, but scratches readily a copper coin, and is as readily scratched by a knife. Its hardness is therefore about 4. This puts it in the 3rd horizontal column. The structure is fibrous, it lies therefore in the vertical column II. At the intersection of these two columns we find three minerals: aragonite, wollastonite and apatite. The latter two are too hard, leaving only aragonite. As an additional test, we put a drop of acid on our mineral which immediately effervesces vigorously, indicating that it is aragonite. A comparison with the general discussion of aragonite would bear out our conclusion.

While in many cases it may be possible to identity the unknown directly by the tables, the main purpose in using them should be to eliminate the majority of minerals and restrict the unknown to four or five species, the final determination being made after comparing the complete discussion of these minerals with the characteristics of the unknown.

Rare minerals which require refined chemical tests, and many others which occur only as microscopic constituents are omitted. Their inclusion is impracticable and would only overburden and detract from the usefulness of the tables.

ERRATA.

Plate II, read pyrolusite instead of pyrolvsite and fibrous instead of fibrovs.

Plate III, read Hill City instead of Hills City.

Plate XIX, read pegmatites instead of pegmaties.

Plate XXV, read microcline instead of microline.

Page, 58, heading 9, read bismuthinite instead of bismnthinite.

Page 60, heading 12, read galenite instead of balenite.

Page 61, heading 13, read PbTe instead of PoTe.

Page 63, heading 17, read cinnabar instead of cinnaba.

Page 79, invert diagram.

Page 108, footnote, read paragenesis instead of paragenesia.

Page 224, fig. 73, read wulfenite instead of wulrenite.

Page 228, Calcium group, read dolomite instead of columite.

Index of Minerals Described

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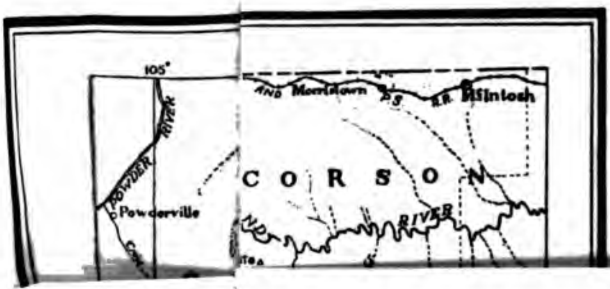
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